Analysis of ATC Operational Feasibility for Potential Near-Term Wake Turbulence Procedures

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Introduction

- **This briefing documents the details of the operational analysis for which the major findings were presented in "Findings from Analysis of ATC Operational Feasibility for Potential Near-Term Wake Turbulence Procedures," F064-B03-033, dated 31 August 2003**
  - **The previous briefing described the following elements of the operational analysis**
    - **Objectives**
    - **Background**
    - **Approach**
    - **Candidate procedure descriptions**
    - **Conclusions**
    - **Next Steps**

Operational Analysis of STL Controller HITL Simulations

Outline

- A series of three HITL simulations were completed to explore the ATC feasibility of a proposed near term rule change for Closely Spaced Parallel Runways (CSPR)
- Evaluations were conducted using STL as the specific test site, with current STL controllers and a NATCA representative
- Candidate procedures for the proposed rule change were developed iteratively with the controllers while
  - Conducting traffic to meet the proposed new rule change
  - Considering potential wake related constraints and ATC operational factors
- Specific evaluation objectives included
  - Determination of the overall ATC feasibility of the proposed new procedures
  - Estimates of controller workload while performing the candidate procedures
  - Determination of arrival and departure rates under various arrival configurations
  - Identification of issues related to the interaction of the candidate arrival procedures with departure and other surface operations
  - Evaluation of aircraft spacing, both along track and vertically at various points in the approach
  - Controller feedback on utility and usability of the candidate procedures and potential training requirements

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The Proposed Rule Change

- Current FAA Order 7110.65 requires treating CSPR that are less than 2500 ft apart as single runway in IMC
  - Implemented to protect a Small category aircraft against the wake of a Heavy category aircraft
- Current FAA Order 7110.65 allows 1.5 nmi diagonal separation for aircraft arriving on runways separated by 2500 ft or more
- The proposal is to modify the 2500 ft rule to 1000 ft for Large and Small category leading aircraft that would enable the application of 1.5 nmi diagonal separation
  - Current rule would be unchanged for 757 and Heavy category aircraft

Current Rule: Min. CSPR Diagonal Spacing (nmi.) for Runway CL Separated >= 1000 ft. and < 2500 ft.				
	Trailing on Adjacent Approach			
Leading	Small	Large	B757	Heavy
Small	2.5/3.0	2.5/3.0	2.5/3.0	2.5/3.0
Large	wv	2.5/3.0	2.5/3.0	2.5/3.0
B757	wv	wv	wv	wv
Heavy	wv	wv	wv	wv

Proposed Near-Term Candidate Procedure: Min. CSPR Diagonal Spacing (nmi.) for Runway CL Separated >= 1000 ft. and < 2500 ft.				
	Trailing on Adjacent Approach			
Leading	Small	Large	B757	Heavy
Small	1.5	1.5	1.5	1.5
Large	1.5	1.5	1.5	1.5
B757	wv	wv	wv	wv
Heavy	wv	wv	wv	wv

- See the appendix for a brief discussion of the basis for this hypothesis and program requirements for its authorization

Summary of Proposed ATC Procedures

- **Two dependent parallel ILS arrival ATC procedures were developed iteratively with the controllers and examined during the simulations:**
  - **6/3 procedure**
    - **The "6" in 6/3 refers to same runway separation between successive arrivals at the point where they are cleared to join the final approach to that runway, and the "3" refers to the separation between the pairs of arrivals on adjacent runways at the turn-on point**
    - **This procedure results in a continuous flow of arrivals to each runway**
  - **7/3 procedure**
    - **In this procedure, arrivals to each runway are vectored to a position about 7 MIT at localizer intercept, and about 3 MIT of the lead aircraft on the adjacent runway**
    - **Requires the lead aircraft of each pair of arrivals to be assigned to a particular runway**
    - **This concept is similar to that currently used with the Localizer Directional Aid (LDA) 12L and ILS 12R operation, except that there is a required 1.5 nmi minimum separation at the threshold between arrivals on adjacent runways**
  - **Both candidate procedures are expected to enable release of departures between arrivals most of the time**

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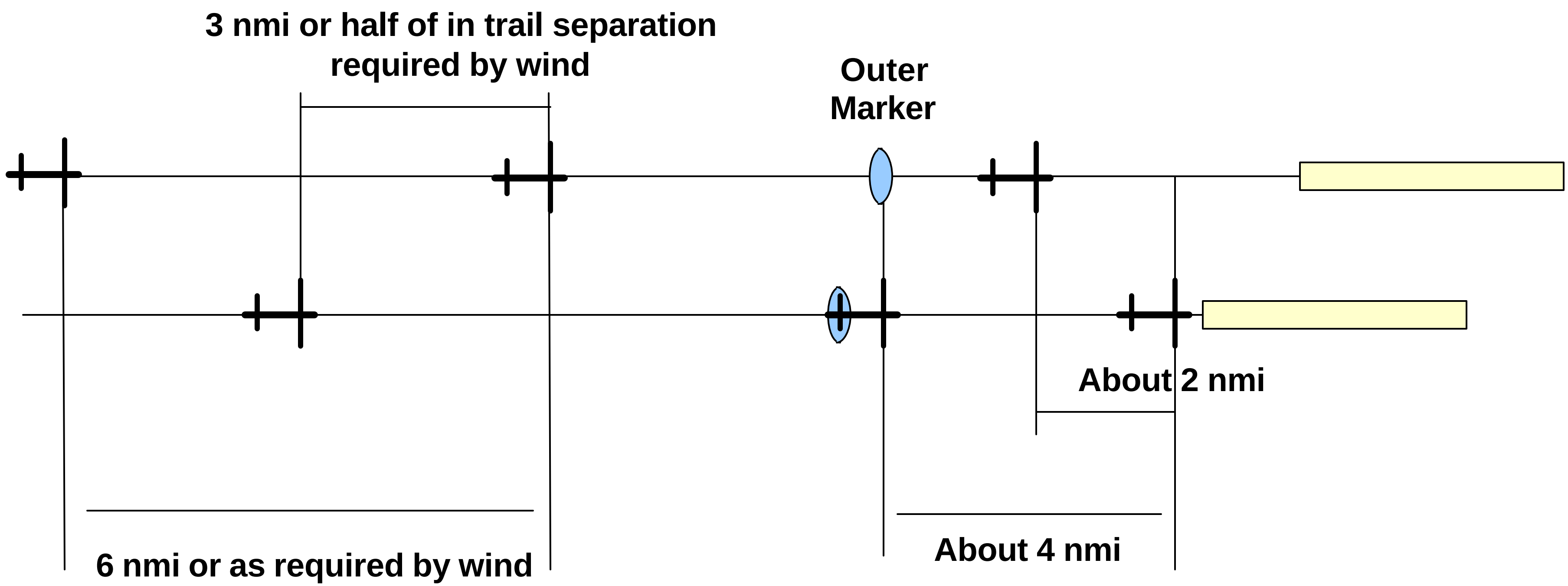
Description of the 6/3 Procedure

At turn on: 6 nmi in trail separation, 3 nmi diagonal
Typical spacing at threshold: 4 nmi in trail and 2 nmi diagonal



All spacing values are approximate examples of spacing achieved
Figure depicts Large and Small aircraft only

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Description of the 6/3 Procedure

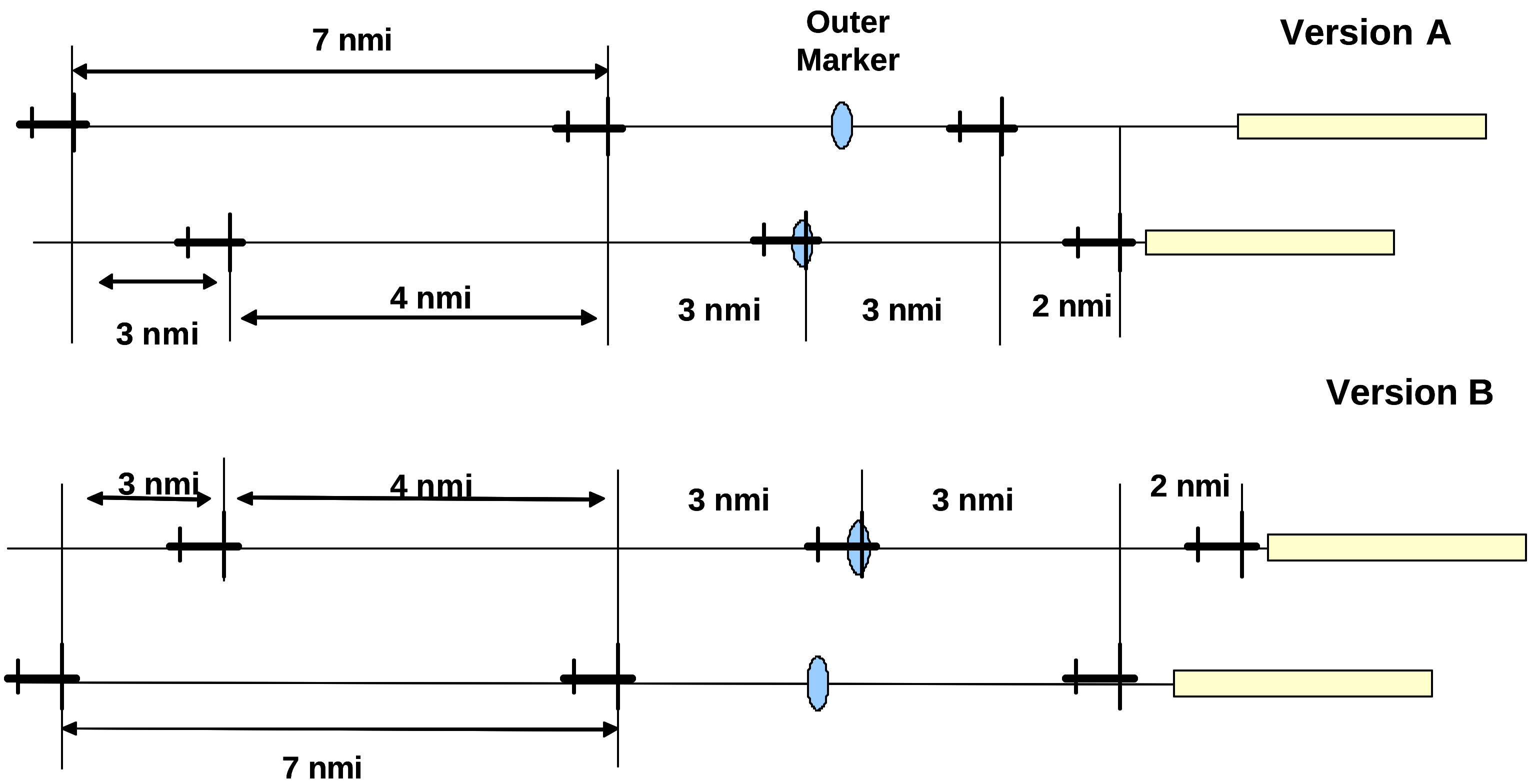
The symmetric candidate procedure illustrated on the previous page is called the 6/3 procedure. Controllers vector aircraft to an in-trail separation of 6 nmi at the localizer intercept on each runway. This separation may typically result in in trail separation at the threshold of 4 nmi or more on each runway, allowing the local controller to release a departure for each arrival. Diagonal separation of 3 nmi between adjacent aircraft at localizer intercept provides adequate separation to accommodate the compression effects of aircraft speed reductions around the Outer Marker and additional compression effects from tail wind to head wind transitions along the final approach. Typical delivery of diagonal separation as measured at the threshold is expected to be 2 to 2.5 nmi.

The depiction of the 6/3 procedure presented on the previous page shows the relative positioning of Large and/or Small when a 1.5 nmi diagonal separation minimum can be applied between them. Standard wake separation is required behind Heavy and 757 aircraft. No specific runway assignment is required for Heavy or 757 aircraft, nor is there a leader-trailer assignment to a specific runway. The Heavy or 757 aircraft are thus expected to be turned on final with no paired aircraft trailing. This essentially implies "skipping a slot" when heavies or 757s are present. The 6/3 configuration resumes after the trailer to the Heavy or 757 aircraft.

The implementation of a 1.5 nmi diagonal separation minimum applies to final approach when both lead and trailing aircraft are established on the localizers. Standard radar separation must be provided until both aircraft are established on the localizer. Vertical separation is applied at localizer intercept to protect against blunders or overshoots.

Description of the 7/3 Procedure

At turn on: 7 nmi in trail separation, 3 nmi diagonal
Typical spacing at threshold: 5 nmi in trail and 2 nmi diagonal



All spacing values are approximate examples of spacing achieved
Figure depicts Large and Small aircraft only

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Description of the 7/3 Procedure
(Versions A and B)

Two versions of the asymmetric 7/3 dependent candidate procedure are presented on the previous page. This procedure was designed specifically to investigate operational issues related to a potential requirement to assign the lead aircraft of an arrival pair to a specific runway. In this concept of use, the in trail separations of 7 nmi at the localizer intercept are provided by the controllers for arrivals on each runway. This initial separation would be expected to deliver in trail separation at the threshold of 5 nmi or more on each runway, allowing the local controller to release one departure for each arrival. Diagonal separation of 3 nmi at localizer intercept provides adequate separation to accommodate the compression effects of aircraft speed reductions around the Outer Marker and additional compression effects from tail wind to head wind transitions along the final approach. Typical delivery of diagonal separation at the threshold are expected to be 2 to 2.5 nmi.

Version A of the 7/3 concept of use presented on the previous page shows the lead aircraft runway assignment typical of today's operations at STL. This is an adaptation of the techniques used during the Localizer Directional Aid (LDA) approach where the aircraft on the left runway fly the offset LDA localizer and use visual separation to turn in behind the aircraft on the right runway as they join the final approach for the left runway. Both Versions A and B require the Heavy and 757 aircraft to be trailers in a pair of aircraft, or to be unpaired on arrival. Version A requires Heavy aircraft to be assigned to the right runway with the lower glide slope. Version B requires both Heavy and 757 aircraft to be assigned to the right runway.

Version B may provide a benefit in that the Local controller may be able to provide visual separation between the lead and trailing aircraft at lower ceilings and release departures with smaller in-trail gaps on the same approach.

Standard radar separation is provided until the aircraft are established on the localizers.

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CAASD ATM Laboratory Configuration

- The simulations were conducted interactively using the facilities of the CAASD ATM Laboratory
  - Initial simulations used for improving fidelity through controller feedback
- Approach control simulation
  - A feeder, final controller configuration with displays for each controller
  - Emulated ARTS III displays at STL
  - Video maps of the STL terminal airspace
- Tower simulation
  - One local controller, using two CRT displays, emulating a BRITE and ASDE display
  - Aircraft departure performance modeled after Total Airspace and Airport Modeller (TAAM)
  - Capability to create surface traffic, model movement from a holding short position to a takeoff hold position, and then to departure
- Pseudopilots controlled aircraft using a keyboard and graphical user interface (GUI)
  - Flight technical error was not modeled
  - Controllers and pseudopilots communicated via microphones and headsets, except that no communication was simulated between the pilots and the tower controller

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CAASD ATM Laboratory Configuration

The simulations were performed at the CAASD Air Traffic Management Laboratory. For this study the laboratory was configured with displays for each controller (four Sony 2k x 2k, 28 inch CRTs) and equipped with standard video maps of the STL terminal airspace. A feeder and final control configuration was simulated. The ATM Lab displays and associated functions emulated the Automated Radar Terminal System (ARTS) IIIE systems used at STL. This lab has been used for developing and evaluating concepts for approach control for over 20 years, and has been considered very satisfactory for these purposes by all controllers over that time.

STL tower operations were simulated using two CRT displays. The first display emulated the capabilities of the Bright Radar Indicator Tower Equipment (BRITE) for monitoring traffic on the final approach. The second display was a surface operations display similar in function to an Airport Surface Detection Equipment (ASDE) system. This display used a high position update rate (1 Hz) to more closely emulate surface movement as might be directly visible from the tower by looking out the window. Actual tower out the window visual operations were not simulated. The ATM Lab infrastructure includes the capability to create surface traffic, and then model surface movement from a holding short position to a takeoff hold position, and then to departure. This capability was used to model the interactions between arrivals and departures during Simulation 1 and 2.

Pseudopilots controlled the aircraft using a keyboard and graphical user interface which listed the aircraft under their control. After selecting a desired aircraft, they entered speed, altitude, heading and approach commands in response to controller instructions. Aircraft descent and deceleration performance was modeled based on aircraft type and was constant within type. Flight technical error is not modeled.

For surface operations ATM Lab staff created aircraft holding short of the runway, and then responded to tower controller instructions to taxi aircraft into position on the departure runway. When the tower controller judged from the BRITE display that the arriving aircraft would be properly separated from the departure, he would issue a takeoff clearance. Aircraft departure performance was modeled after that used in the TAAM for EMB145 and MD80 aircraft. The tower controller deemed the lab adequate for making judgments regarding when departures could be released.

Feeder and final controllers and pseudopilots communicated via microphones and headsets. Controllers were able to use standard equipment push-to-talk or foot switch activation for transmissions according to their preference. Normal handoff procedures were used between feeder and final controllers. Communication between pilots and the tower controller were not simulated.

Lab Simulation Participants

- **Each simulation was conducted with a team of full performance level controllers working the final approach position**
  - **Each final approach controller worked traffic to one of the two parallel runways, 12L and 12R**
  - **Simulation 1 included a single feeder controller from STL who sequenced traffic to both final controllers**
  - **Simulations 2 and 3 used a controller from STL and a controller union representative working a separate feeder positions for each final approach controller**
- **A tower controller from STL was also included for Simulations 2 and 3**
  - **Responsible for monitoring the flow of arrival traffic and issuing takeoff clearances to departing aircraft**
  - **Provided valuable insight into the coordination procedures between tower and TRACON for managing arrival spacing to accommodate departures, and tower and ground control for managing runway crossings to the ramp**

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Lab Simulation Participants *(Concluded)*

- **Traffic was controlled by four pseudopilots, one for each working controller**
  - **Pseudopilots controlled their aircraft by entering speed, altitude, heading, and approach commands through a workstation interface**
  - **Each was responsible for controlling a subset of the aircraft in the scenario**
  - **Each communicated with their controller via headset and microphone using standard ATC voice communication procedures**
- **For Simulation 3, pilot observers from one of the pilot unions were present and they observed operations from the remote Demo Room of the CAASD ATM Lab facility**
  - **Communications and controller display for one of the two final approach controllers was routed to the demo room display system to assist in their monitoring of the final controller actions**

Lab Simulation Variables

- **Simulations were designed to vary and study the effects of the following factors**
  – **Approach procedures and variations**
    - **Procedures as described earlier including transitions to and from the current LDA procedures**
    - **Variations as described in the appendix of this briefing**
  – **Nominal traffic arrival rates**
  – **Variation in wind conditions**

Lab Simulation Variables
Traffic Scenarios

- Scenario traffic model was based on actual STL traffic flow taken from 27 February 2003 and then modified with input from the STL controller team
  - Departure flows were not simulated, but departure clearance operations were included
- Each scenario replicated the same basic traffic flow, but with several variables, including
  - Arrival rate
  - Number of Heavy and Boeing 757 aircraft to reflect typical STL traffic
  - Wind conditions
- Simulation 1 used the arrival rates of the traffic sample described above
- As a result of controller input, three nominal arrival rate models were developed for Simulation 2 as more appropriate for the study: 42, 52, and 60 aircraft per hour
  - Rate values indicate nominal rates in the traffic scenarios; the achieved arrival rates depend on actual control and are reported later
  - During Simulation 2 it was determined that the 60 rate was not sustainable, requiring “deletion” of aircraft (simulating holding) in order to keep controller workload at realistic levels and to more accurately simulate STL terminal operations
- Simulation 3 used only the 42 per hour and 52 per hour rates
- Allocation of B757 and Heavy jet arrivals
  - 2 B757s and one Heavy jet for the 42 rate, and 3 B757s and one Heavy jet for the 52 rate
  - This proportion of 757 and Heavy jets was typical at STL for the arrival rates simulated

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Lab Simulation Variables
Traffic Scenarios

The scenario traffic modeling was based on actual STL traffic flow taken from February 27, 2003 and then modified with input from the STL controller team. The mix of traffic included Small, Large, B757 and Heavy jet arrivals. Departure flows were not simulated, but departure operations were included to the extent required to examine departure rate capabilities during the various arrival configurations. Each scenario replicated the same basic traffic flow, but with several variables, including nominal arrival rate, wind condition, number of Heavy and Boeing 757 aircraft. These variables were variously applied to the scenarios over the course of the three simulation events. The variables were counter-balanced across scenarios within a simulation to the extent possible, to preclude the occurrence of order effects.

Lab Simulation Variables
Wind Conditions

- For Simulation 1, two terminal wind profiles were created
  - Headwind component on the final approach path at all levels decreasing in velocity as the aircraft neared the surface
  - Tailwind component on final changing to a headwind component at the surface
    - Significant compression occurs in such tailwind-to-headwind wind conditions and creates additional workload in planning and vectoring for correct initial spacing as the aircraft join final
- During Simulation 1, controllers determined that a more extreme tailwind-to-headwind profile was required, and such a profile ("Flip" wind) was added
- Flip profile included a tailwind component in excess of 40 knots approaching the localizer at vectoring altitudes, changing to a headwind of about 10 knots at the surface
- For Simulation 2, at controller request, wind data from the recently commissioned Integrated Terminal Weather System (ITWS) was used to develop a more moderate "real world" wind profile
- For Simulation 3, both the ITWS profile and the Flip profile were used and a third headwind profile (East wind) was added to extend the applicability of results to a broader set of operational conditions that might exist at other airports
  - The new headwind profile included crosswind components from the northeast, requiring different vector planning by controllers
  - Compression was not as severe in this wind condition since it resulted in headwinds along the complete final approach

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Lab Simulation Variables
Wind Conditions

Several different wind profiles were used over the course of the three simulations. In Simulation 1 two wind conditions were created. The first profile resulted in a headwind component on the final approach path at all levels decreasing in velocity as the aircraft neared the surface. The second profile included a tailwind component on final changing to a headwind component at the surface. This profile was created in response to input from the controllers, who noted that a tailwind-to-headwind condition was common when operating in the east arrival configuration (LDA or ILS approaches to the parallel Runways 12L and 12R). In addition they advised that significant compression occurs in such wind conditions and creates additional workload in planning and vectoring for correct initial spacing as the aircraft join final.

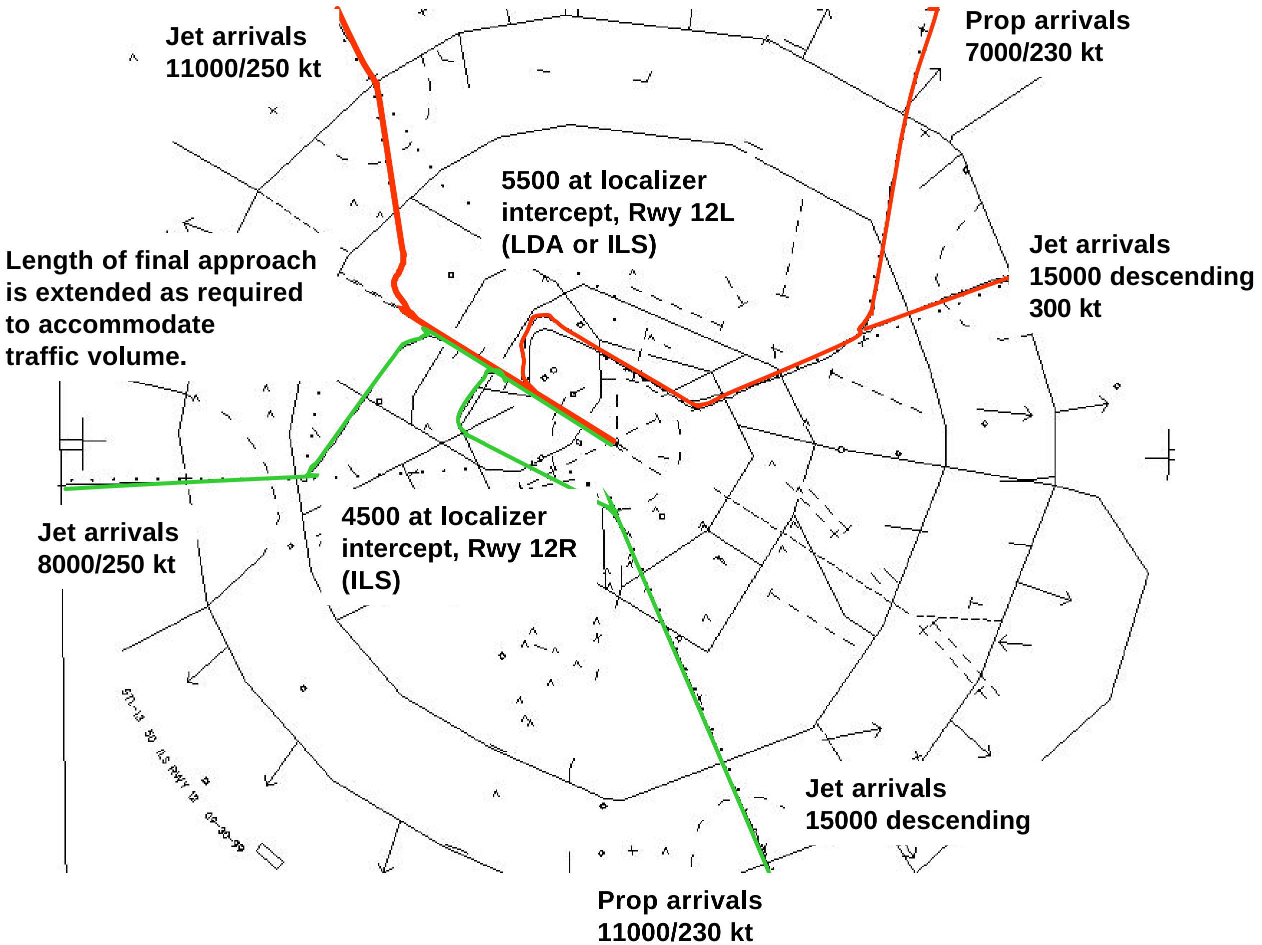
During the course of Simulation 1 the wind profiles were further modified in response to controller input until the apparent speed behavior of the aircraft more closely matched their “worst case” experience in working actual traffic. This profile is referred to below as the “Flip” wind. The Flip profile included a tailwind component in excess of 40 knots at vectoring altitudes, changing to a headwind of about 10 knots at the surface. Controllers advised that this was a fair representation of the most extreme wind condition they would be likely to encounter when landing to the southeast.

For Simulation 2 wind data from the recently commissioned ITWS was used to develop a more moderate “real world” wind profile. While this profile also included a tailwind at altitude, changing to a headwind at the surface, the magnitude of the change was not as extreme as the “worst case” condition described above

In Simulation 3 the ITWS profile and Flip profile were used, and a third headwind profile (East wind) was added. This was a continuous headwind profile which included crosswind components from the northeast, requiring different vector planning by controllers. Compression was not as severe in this wind condition. This profile was included to extend the applicability of results to a broader set of operational conditions that might exist at other airports.

STL Terminal Airspace

Typical Arrival Paths



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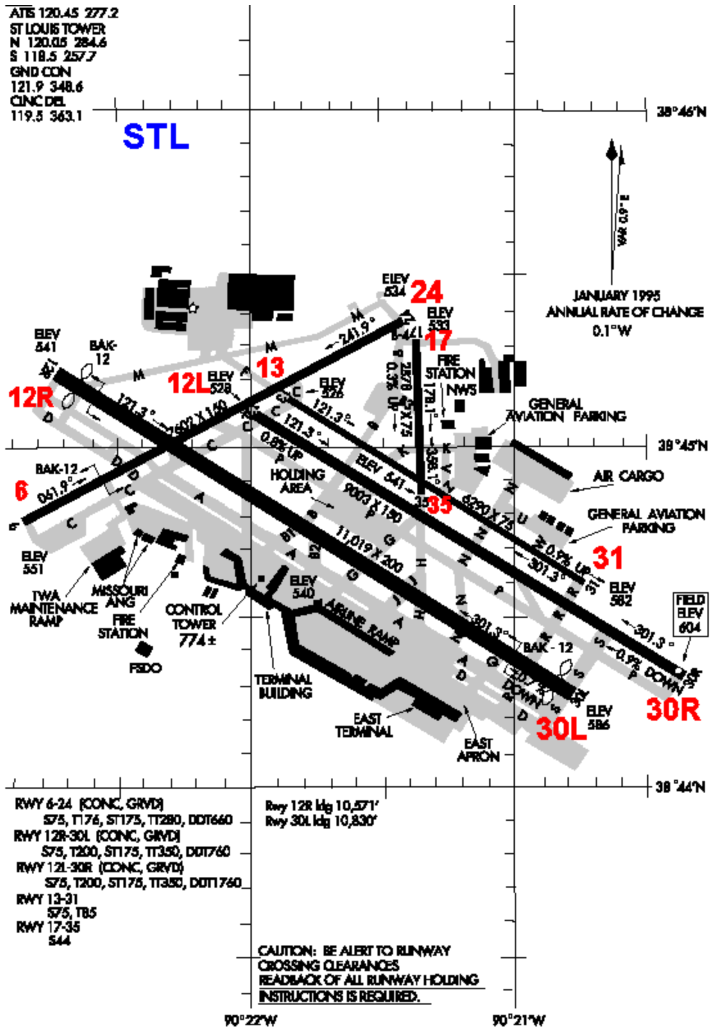
STL Airport Diagram



Runway 12L threshold is staggered 3500 ft past the threshold of Runway 12R

Runway centerline separation between 12L and 12R is 1300 ft

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Data Collection from HITL Simulation

- Basic aircraft position data, altitude, and distance from threshold for each arrival were collected automatically at 1 Hz by the data collection system
- Data saved after each scenario run for post processing to derive information on
  - Inter-arrival pair spacing
  - Same runway spacing
  - Distance from threshold when certain spacing criteria were met
- After each scenario, controllers completed a workload assessment and provided feedback on the scenario during an oral debriefing

Results of Controller Simulations

- ATC feasibility
- Controller workload
- Achieved operational rates
- Relevant spacing data

ATC Feasibility

- Procedures/techniques developed iteratively
  - Several initial proposals and evaluations in Simulations 1 and 2, including some fractional spacing (e.g., 5/2.5), that lead up to the final proposals for Simulation 3
- Approach Control
  - Basic feasibility and workload issues
    - Spacing at turn-on and differences by aircraft type
    - Requirement to coordinate spacing to the two runways
    - Workload in assigning aircraft to specific runways
    - Procedures for assigning and integrating Heavy and B757s
  - Requirement to provide 1.5 nmi diagonal separation

ATC Feasibility

Candidate ATC procedures were developed iteratively with the controllers. Several proposal were discussed based on the need to deliver no less than 1.5 nmi between aircraft on parallel approaches and the need to accommodate departures. Numerous operational issues are involved in assessing the basic feasibility of a procedure. Some of these are listed in the accompanying bullet chart. Of all the issues, determining the initial separations on turn-ons may be considered one of the most significant, because of its affect on many of the other issues. Much of the work culminated in developing these initial separations.

Initially, in Simulations 1and 2, tighter in-trail spacing on the same runway was considered, including fractional values (e.g., 5/2.5 nmi procedure). The controllers indicated that when parallel approaches are in use, they still vector traffic with respect to the preceding traffic on the same runway only,* and that they prefer to make adjustments to *spacing in whole mile increments*. When the restrictions for heavies and 757s were added, the computations for the in-trail separations became too complex to deal in real time. As a result, procedures with fractional increments as basic procedures were not considered any further. Ultimately, the two candidate procedures described earlier (6/3 and 7/3) were developed as being satisfactory from all points of view.

Currently, STL operations do not have a hard requirement to coordinate flows to the two runways. Leading/trailing assignments and spacing are recommended but not mandatory in current LDA operations. The proposed operations required specific leading/trailing requirements with specific minimum spacings. The specific leading/trailing requirements were considered workable. The 1.5 nmi minimum spacing created a greater workload for a 5/2.5 nmi procedure since a 2.5 nmi diagonal separation may more often collapse to 1.5 nmi due to compression. Neither the 6/3 nor the 7/3 candidate procedures were considered to produce excessive workload in this regard, because the required 1.5 nmi minimum separation was delivered as a a matter of course with this spacing. The tower controller never considered this new requirement to produce excessive workload.

Requirements for assigning Heavy and 757 aircraft and the procedures for assuring adequate separations behind them were a significant consideration with respect to workload. The 6/3 procedure was the simplest: a slot was simply skipped behind either a Heavy or a 757. A version of the 7/3 procedure developed for Simulation 2 was considered very difficult by the controllers. This is reflected in workload measurements that are reported later in this briefing. In Simulation 3, this procedure was simplified. In both 7/3A and 7/3B, heavies or 757s were required to be the trailing aircraft, and in both cases, heavies were restricted to the right runway. In procedure 7/3A, Heavies “went alone” whereas 757s could be on either approach, and a mile was added on both approaches. In 7/3B, an additional 3 nmi were added behind either the Heavy or the 757 on the low approach. These modifications resulted in the 7/3 procedures being considered workable.

*** Note: A required exception is that one controller will vector to three MIT of the aircraft on the parallel runway to set up the initial pair in the arrival flow. Thereafter each controller need only vector in relation to their own traffic in order to maintain the desired configuration - 6 or 7 MIT depending on the procedure.**

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ATC Feasibility *(Continued)*

- Airspace Issues
  - Turn-on altitudes (5500 and 4500 ft respectively)
  - Required length of final for adequate control (about 20 nmi)
  - Available airspace and separation buffers needed near capture
  - Effect of winds
- Spacing Requirements on long final
  - Current procedures authorize 1.5 nmi for dependent parallel approaches along the entire length of final approach
- Accommodating variations for operational factors such as winds and departures

ATC Feasibility *(Continued)*

Numerous airspace issues were investigated and resolved. The controllers experimented with various altitudes for turn-on, including co-altitude; They finally converged on turning approaches to 12L at 5500 ft MSL and to 12R at 4500 ft MSL, same as the current LDA procedures, which gave them adequate lengths on final approach to attain the required spacing for the traffic levels handled. Final approach courses of about 20 nmi or more would be required for these procedures when traffic conditions require ILS capture at 5500/4500 ft.

Winds on long final for the two approaches make the airspace issue challenging in that the two aircraft can be traveling at significantly different speeds due to different tail winds, causing significant compression values. An option to descend the trailing aircraft in order to get into the same wind field may not be available if the left aircraft is leading (as in procedure 7/3B) since he must wait until the leading aircraft is established on its localizer before losing 3 nmi. There were significant differences between procedure 7/3A and 7/3B in this regard. The controllers agreed that the 7/3A procedure was far superior in terms of the flexibility and ease of maneuvering at turn-on. The 7/3A procedure also requires the least changes from current LDA operations.

Of course any basic operational procedure must be capable of responding to operational variations such as increased winds or greater departure demand. Both procedures (6/3 and 7/3) were considered robust and capable of accommodating such variations. Three such variations are described in detail in the appendix, and involve using either extra spacing or reduced spacing to accommodate the required conditions.

ATC Feasibility *(Concluded)*

- **Tower**
  - **Departure operation**
    - **Considered both visual and non-visual procedures**
    - **Non-visual (hard IFR) assumed throughout Simulation 3**
    - **Considered acceptable for both candidate procedures**
- **Two basic procedures/techniques developed**
  - **6/3 was considered easier than the 7/3 procedure; and 7/3A was considered easier than 7/3B. All were considered workable**
- **Simulations thus established basic ATC feasibility of the proposed new rule change**

ATC Feasibility *(Concluded)*

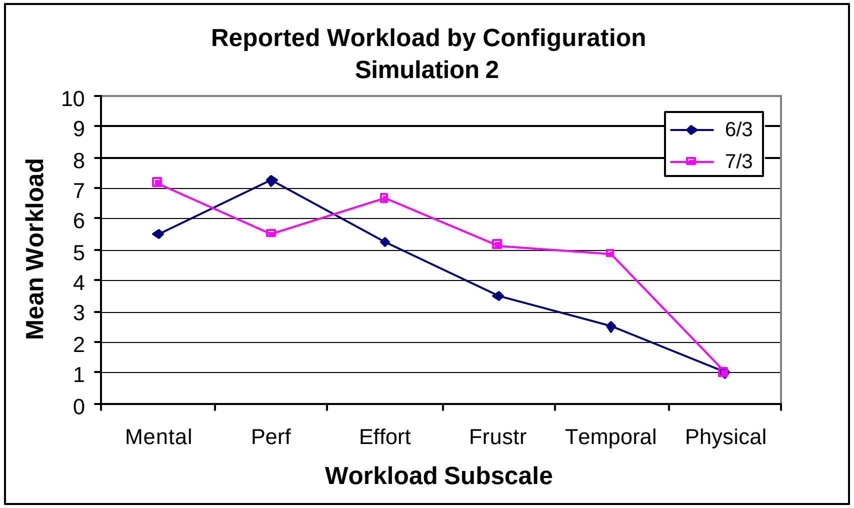
As described previously, the tower controller considered the fidelity of the simulation adequate for purposes of determining whether aircraft could be cleared for departure. Different visibility conditions were assumed for different simulations, including some at good visual conditions, so that a departure can be launched whenever an adequate spacing on same runway is available, to low IMC, where visual separation from the aircraft on the other approach can not be provided and at least 2 nmi increasing to 3 must be provided from aircraft on either approach before an aircraft can be launched. In Simulation 3, all scenarios were conducted assuming low IMC.

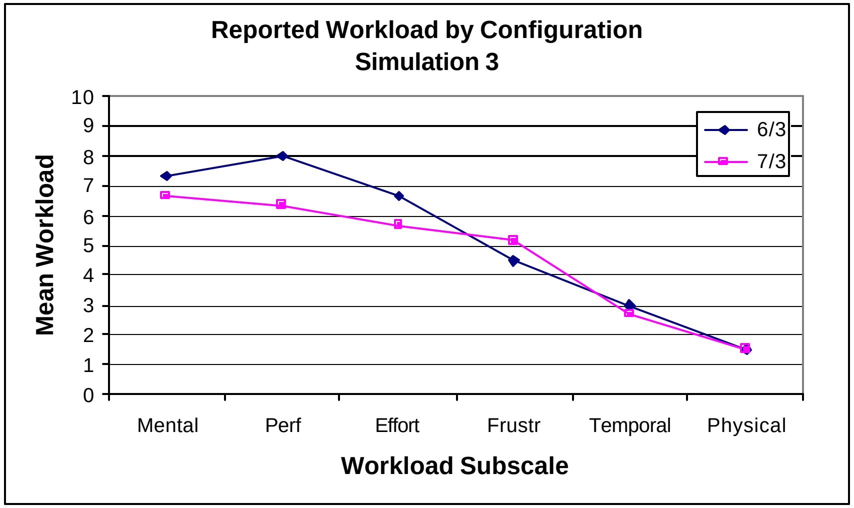
The 6/3 and the 7/3 candidate procedures were both considered adequate for departures, being capable of launching a departure for nearly every arrival. Departure counts provided later quantify this observation. Monitoring the 1.5 nmi separation for potential violations was not considered an undue workload by the tower controller.

In summary, controllers from STL were able to develop at least two procedures that would be acceptable for operations in IMC. They indicated that such a procedure would offer a significant advantage in poor weather conditions in that an effective operational alternative would then be available.

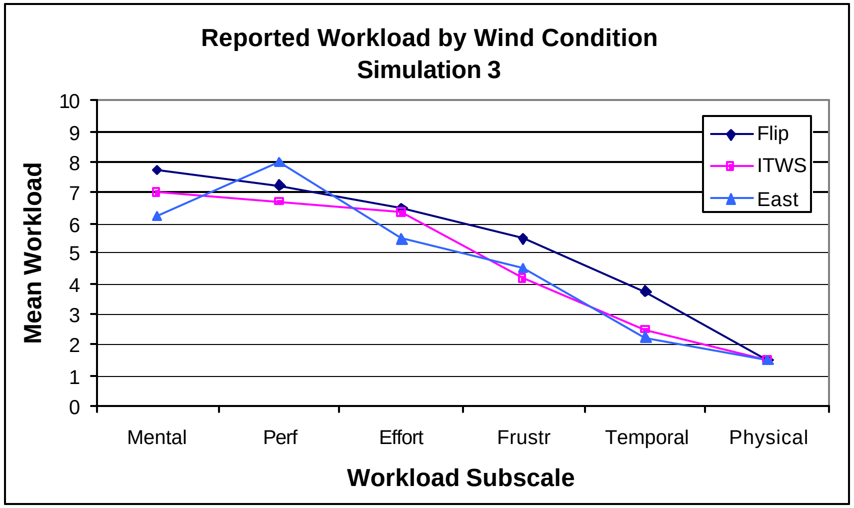
Reported Workload

Simulation 2 and Simulation 3





During Simulation 2 the 7/3 procedure was assessed to be more difficult. However, that procedure was modified for Simulation 3 and was then considered almost as workable as 6/3. Although not shown here, 7/3A was preferred over 7/3B because it offered fewer airspace issues on long final and also required minimal change over current operations.



In Simulation 3, controllers reported somewhat higher frustration and greater time pressure in the Flip wind than in the other conditions.

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Reported Workload
Simulation 2 and Simulation 3

At the end of each scenario the final controllers completed a workload assessment (modified NASA TLX, unweighted, Hart and Staveland [1988]). This method is a simple paper and pencil technique in which controller rate their own workload in six categories: Mental, Performance, Effort, Frustration, Temporal and Physical. After each scenario the controllers rated each subscale from 1 to 10, with 1 indicating low workload and 10 the maximum workload. The data was averaged across the indicated conditions and the graphic profiles are displayed.

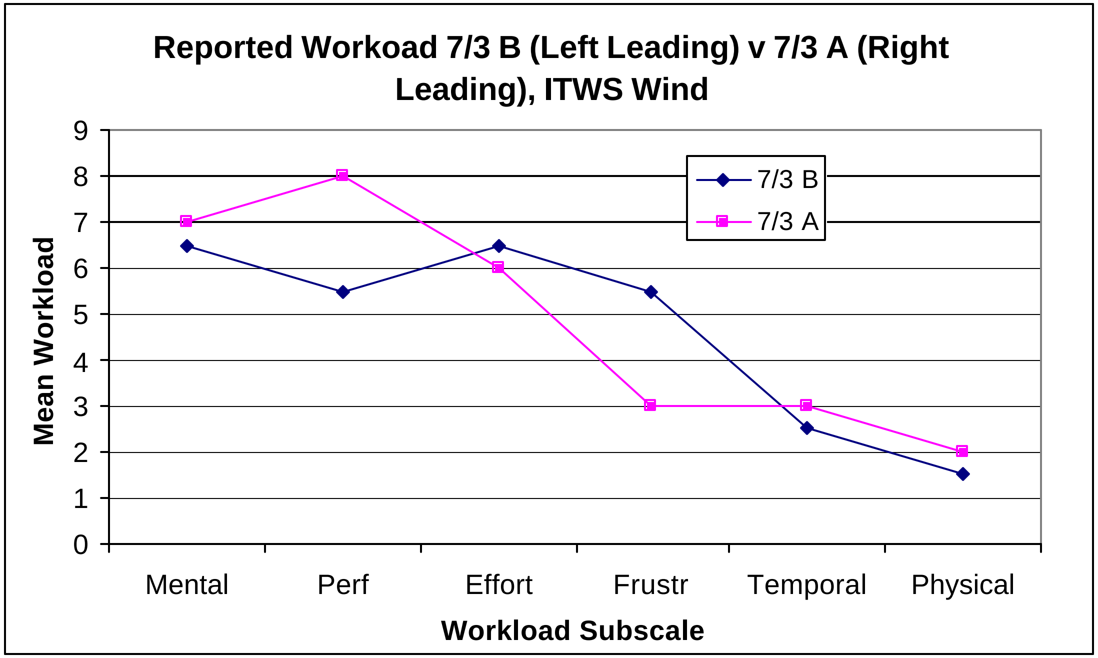
The workload data for Simulation 2 and Simulation 3 is presented below. The two upper panels compare Simulations 2 and 3 workload data by arrival configuration, either the Base 6/3 Continuous procedure or the Base 7/3 staggered pairs. In Simulation 2 there was a consistent finding, corroborated during the debriefings, that the workload associated with the 7/3 procedures tended to be higher, and the controllers rating of their own performance (see the Performance subscale) lower in that condition.

In Simulation 3, the difference is much less pronounced, and even showing some benefit to the 7/3 procedure in the controller assessment of own performance. Although this may partly be due to learning over the course of the three simulations, it was largely due to the changes in method (7/3 Version B) of execution of the 7/3 technique which reduced the mental effort required to plan and execute the vectoring required to accommodate B757 and Heavy Jet arrivals.

In Simulation 2 Heavies or 757s could be assigned to either runway. The right runway was designated as pair leader, with the left runway traffic following (7/3 Version A). When a 757 or Heavy Jet was a member of the pair as trailer, controllers were required to provide additional spacing to meet the wake turbulence separation criteria behind those aircraft. This in turn required additional mental effort to estimate the turn on distance behind the aircraft inbound to their respective runways, based on the additional increment of distance required by the 757/Heavy. Under conditions of high workload, controllers found this mentally challenging ("Heavy ciphering" as they called it) and this was reflected in the generally higher workload ratings.

Finally, the reported workload by wind condition across configuration is presented. This shows, on average, a slightly higher workload, on lower performance in the Flip Wind condition which required the most planning by controllers to adjust for the compression on final approach. This was confirmed during the oral debriefing following each scenario.

Workload
7/3 B versus 7/3 A



Workload
7/3 B versus 7/3 A

During discussion prior to starting data collection for Simulation 3, procedure 7/3 B was designed. It was determined that the (Large or Small) leader would be on the left runway; and all Heavy jets and 757 traffic, which must be trailing, would be routed to the right runway (lower glideslope), and 3 mi would then be added to spacing on both runways to provide the required additional wake turbulence separations. Controllers reported that this simplified the amount of mental effort required to plan spacing behind such aircraft and made the technique more effective. The reported workload by configuration for Simulation 3 reflects the convergence of workload between the two procedures reported by controllers. Later in Simulation 3, procedure 7/3A was designed and was found to be even more effective.

To assess possible workload differences between the two versions of the 7/3 procedure, the results of two scenarios are presented on the preceding page. Scenario 1 which used 7/3 B (with Runway 12 Left leading) and Scenario 9, which used 7/3 A (with Runway 12 Right leading). Both Scenarios were conducted in ITWS winds, a moderate tailwind-to-headwind condition typical of arrival operations using Runways 12L and 12R. During the debriefing controllers reported that the 7/3 A procedure significantly reduced their workload, was an easier transition from LDA operations (same leading runway) and accommodating wake turbulence requirements behind 757 and Heavy jets would be straightforward, by simply not pairing an arrival with those aircraft. These comments are supported by the data below which indicate that the controllers judged their performance to be higher at a lower level of frustration with comparable workload in the other workload subscales.

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Achieved Arrival and Departure Rates by Scenario for Simulation 3

Scenario	Wind	Config	Achieved Arr Rate/Hr	Achieved Dep Rate/Hr
1	ITWS	7/3 B	47	40
2	Flip	7/3 B	46	50
3	East	7/3 B	47	42
4	ITWS	6/3	54	43
5	Flip	6/3	54	51
6	ITWS	LDA to 7/3B	49	49
7	East	LDA to 6/3	46	46
8	ITWS	7/3 A	46	47

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Achieved Arrival and Departure Rates by Scenario for Simulation 3

As seen in the table, arrival and departure rates were well matched, with departures released at near a one-for-one rate regardless of arrival configuration and wind condition. The tower controller reported that adequate spacing existing to release departures, except under a few close spacing situations. It was his judgment that either the 6/3 or 7/3 procedure would support departure operations, and that there was room to tighten spacing a bit to accommodate an arrival rush. As indicated earlier, during these final simulations, the tower controller assumed that the weather conditions were low IMC, and visual separation rules could not be applied for launching departures. Monitoring workload under Flip Wind was reported to be higher for the tower controller to ensure that minimum spacing was not violated. During the simulation, the tower controller detected several near minimum situations and some (but not all) affected aircraft were advised to go-around.

It should be noted that arrival rates for the current LDA operations in visual conditions is typically about 54 to 60 per hour. It can be seen that the controllers achieved rates close to that with the 6/3 procedure in the simulations. This is not surprising since the LDA operation typically uses 6 nmi in trail for same runway separation.

Spacing Data: Overview

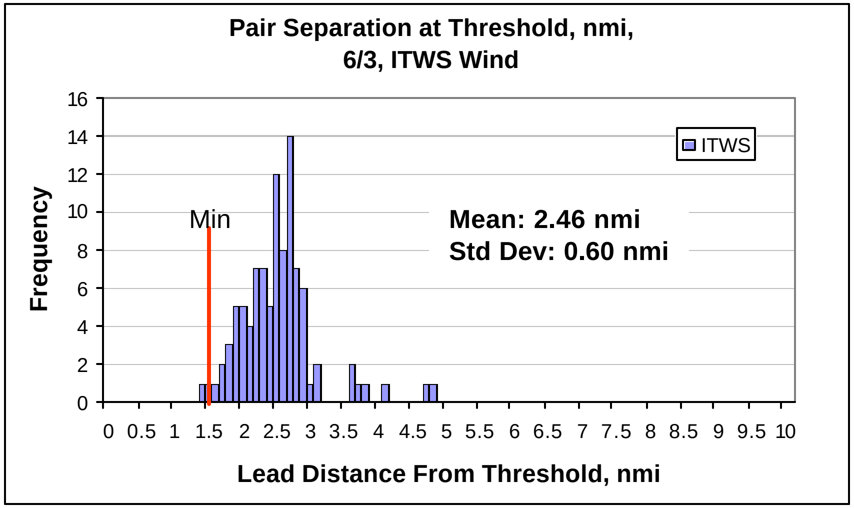
- **Approach spacing data from Simulation 3**
  - **Pair separation at threshold, by wind condition and configuration**
  - **Same runway separation at threshold, by wind condition and configuration**
  - **Lead distance from threshold when selected spacing values are reached, by wind condition, all configurations**

Pair (diagonal) Separation at Threshold

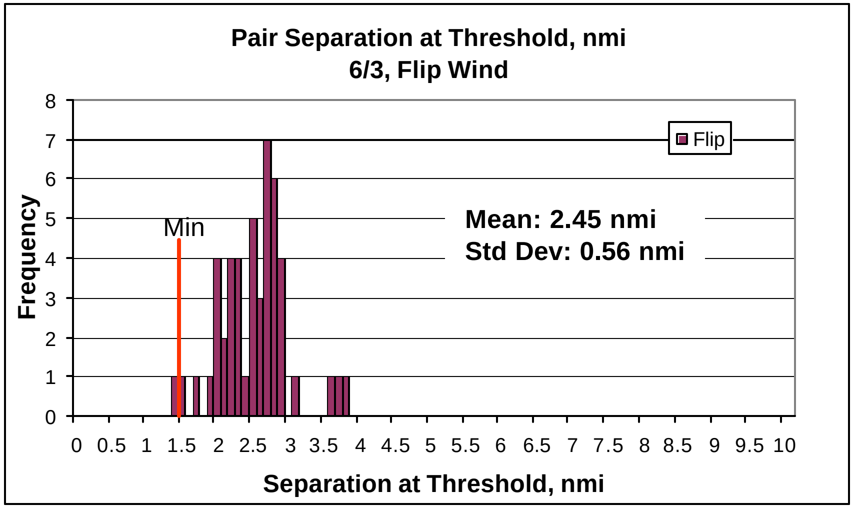
- Pair separation at threshold is the performance standard that must be met by controllers as they sequence traffic to the runway
- The new rule authorizes use of an existing dependent separation standard, 1.5 nmi, between arrivals on parallel runways spaced less than 2500 ft, but at least 1000 ft apart
- It was desirable to verify that controllers were able to deliver aircraft to the threshold using that standard, under a variety of operational conditions

Pair (diagonal) Separation at Threshold, 6/3 Procedure, by Wind Condition

ITWS

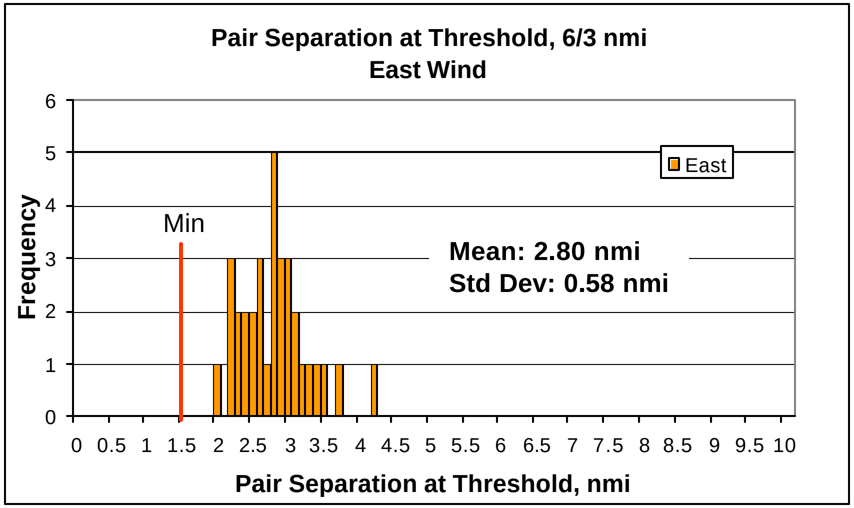


Flip



During the simulation, the tower controller detected several near minimum situations and some (but not all) affected aircraft were advised to go-around. The two cases reported here were not issued go-arounds.

East



Note: Vertical red line is minimum authorized diagonal separation for parallel runway arrivals under the candidate procedures

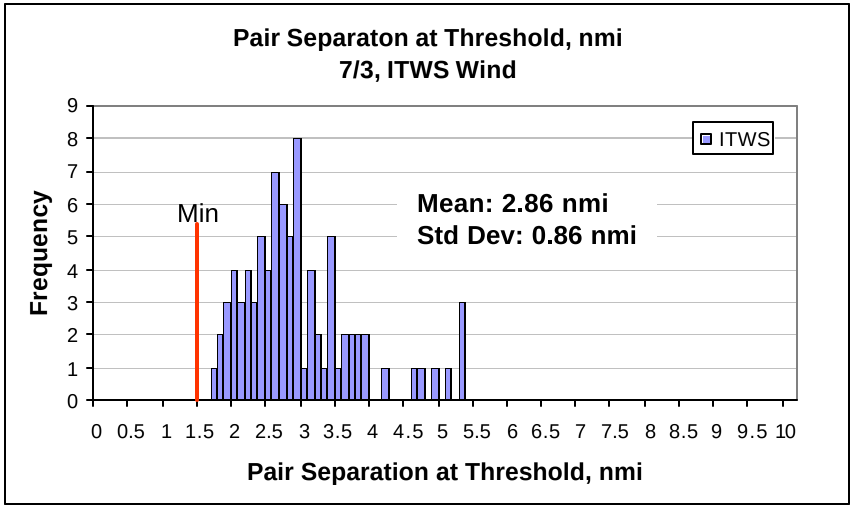
Pair (diagonal) Separation at Threshold, 6/3 Procedure, by Wind Condition

The charts on the preceding page provide distributions of pair separation at threshold by configuration and wind condition. Pair separation is the diagonal separation between successive aircraft on the two parallel approaches. Mean separation and standard deviations are also provided. It can be seen that the minimum separation required by the candidate procedure is in fact provided, with the predominant threshold separations being between 2 and 3 nmi.

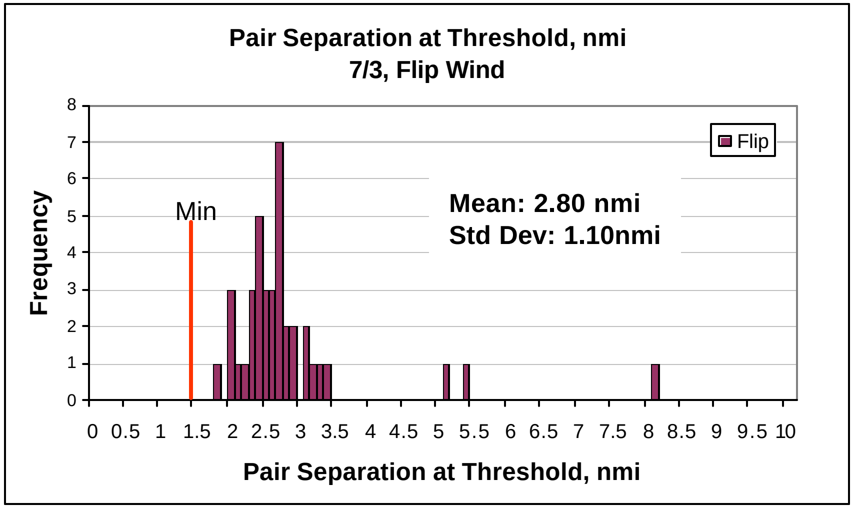
For the 6/3 procedure two data points show a separation of 1.4 nmi, less than the desired 1.5 nmi. Both events occurred early in the runs while controllers may have been still making adjustments in initial spacing to account for the wind. The wind profiles in both cases were tailwind to headwind conditions which result in significant compression inside the final approach fix. During the simulations tower controller noted several situations requiring go around and took action to accomplish them. To do so required a somewhat cumbersome over the shoulder process since the ATM lab communication infrastructure does not currently support Tower-TRACON coordination or direct communication from tower to pseudopilot. Therefore not all aircraft that might require go-arounds in actual operations were necessarily so instructed.

Pair (diagonal) Separation at Threshold, 7/3 Procedure, by Wind Condition

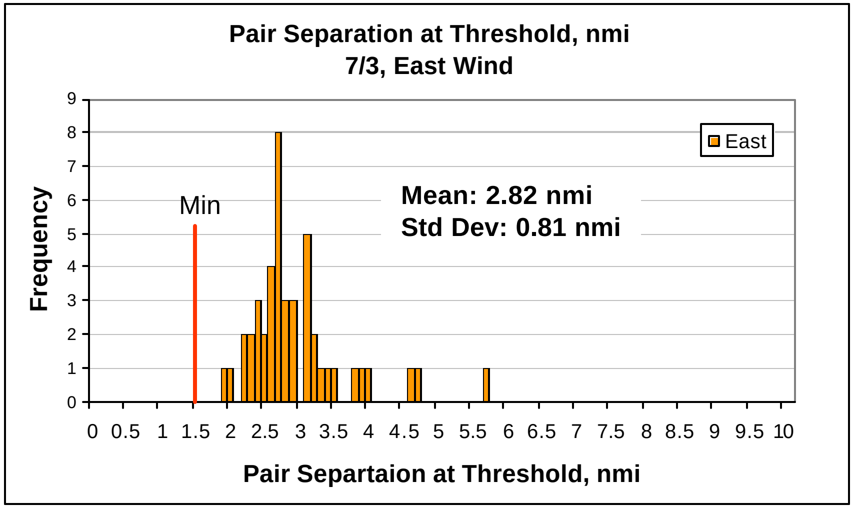
ITWS



Flip



East



Note: East Wind data includes second half of LDA to 7/3 transition Scenario 7.

Vertical red line is minimum authorized diagonal separation for parallel runway arrivals under the candidate procedures.

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Pair (diagonal) Separation at Threshold, 7/3 Procedure, by Wind Condition

The charts provide distributions of pair separation at threshold by configuration and wind condition. Mean separation and standard deviations are also provided. It can be seen that the minimum separation required by the candidate procedure is in fact provided, with the predominant separations provided being between 2 and 3 nmi.

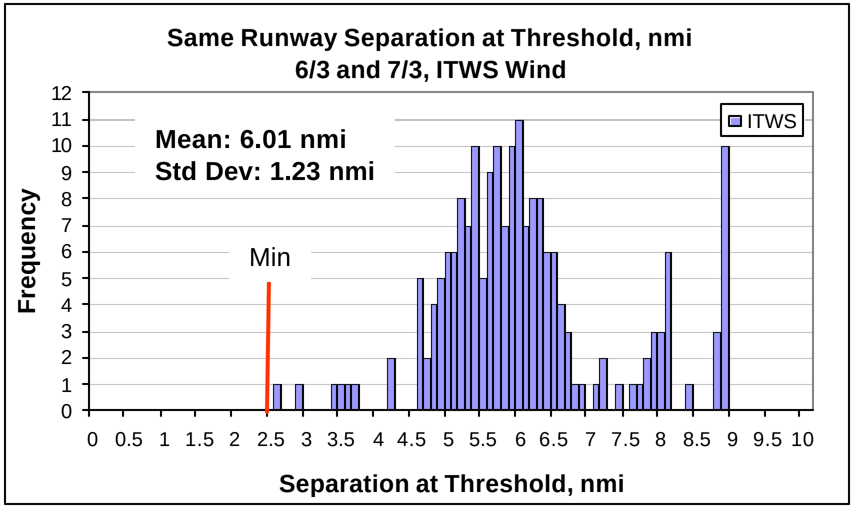
In the 7/3 condition no data points less than 1.5 nmi are seen. In both arrival configurations mean arrival spacing only varied at most by a few tenths of a mile. Given the severity of the Flip Wind profile in tailwind to headwind component, controllers demonstrated the ability to make the necessary spacing adjustments to ensure that threshold spacing was satisfactory.

Same Runway Separation at Threshold

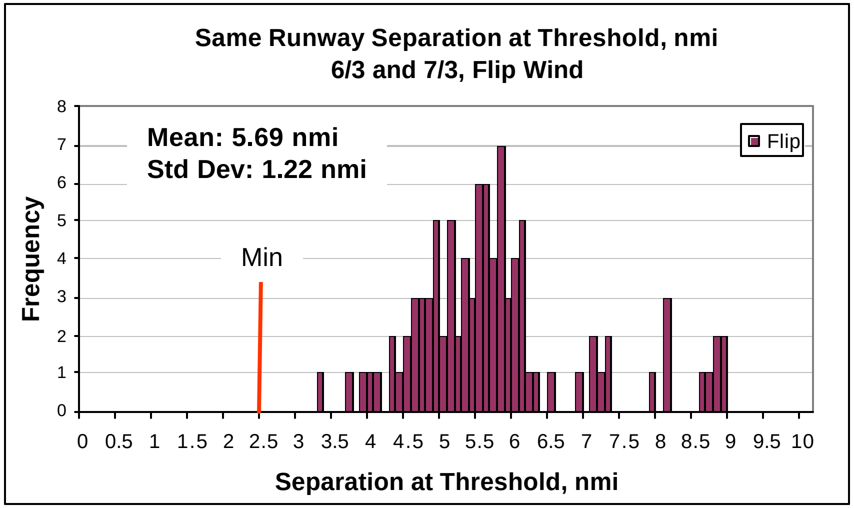
- Adequate separation between aircraft arriving on the same runway is also important to establish the ability to sequence departures between arrivals
- The STL tower controller used simulated tower radar displays to make judgments concerning runway spacing and to determine when to release departures
- Distance between arrivals on each runway was also collected and analyzed to determine if there was a systematic variation in same runway spacing based on wind condition or approach configuration
- The observed runway separations were adequate in all but a few cases to release departures, even when applying IMC separation rules.
- The following charts provide the distributions of same runway spacing at threshold for the various wind conditions and approach configurations

Same Runway Separation at Threshold, 6/3 and 7/3 Combined, by Wind Condition

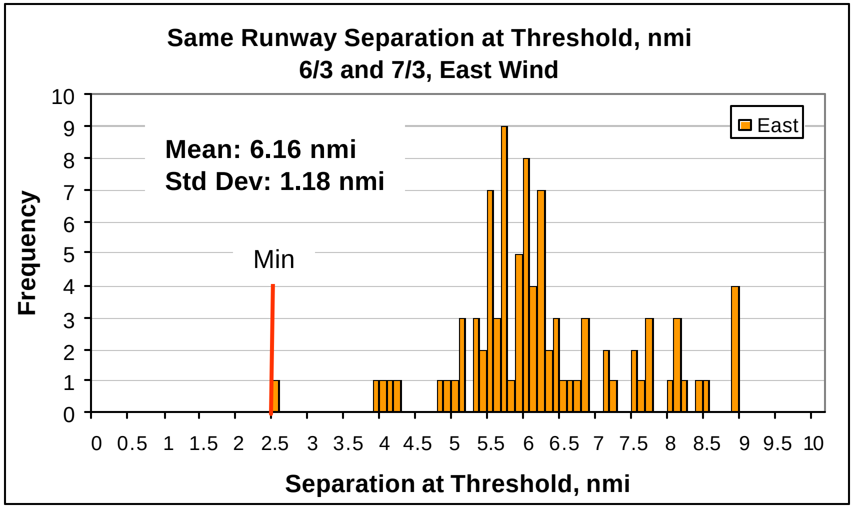
ITWS



Flip



East



Note: Vertical red line is minimum authorized radar separation for same runway arrivals to qualified runways.

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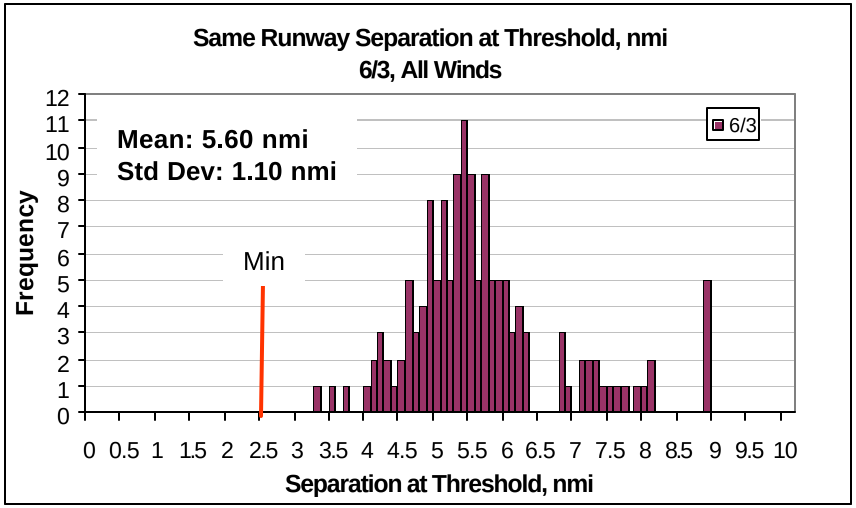
Same Runway Separation at Threshold, 6/3 and 7/3 Combined, by Wind Condition

The charts on the previous page show the distribution of same runway separation at threshold by wind condition, combining both 6/3 and 7/3 data. Means and standard deviations are provided. Note that no aircraft was less than the authorized minimum radar separation of 2.5 miles indicated by the vertical red line. Only a few aircraft were less than 4 MIT to their own runway regardless of wind condition or approach configuration. This has significant implications for the sequencing of departure traffic. The St. Louis tower controller indicated that with four miles separation in trail there would be no difficulty whatsoever departing at least one aircraft between each arrival pair. The timing of the departures would depend on whether visual determination of diverging courses would be possible, or if standard IFR separation would have to be applied. In any event, the average same runway spacing achieved during the simulation would have no adverse effects on departure rates.

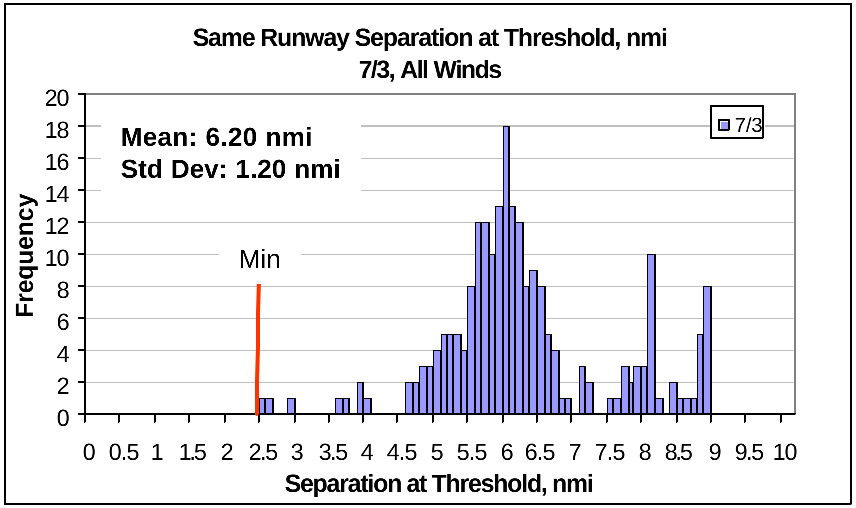
ITWS wind condition data includes spacing from that portion of Scenario 6 when 7/3 procedures were in use. East wind data includes that portion of transition Scenario 7 during which 6/3 procedure was in use.

Same Runway Separation at Threshold, All Wind Conditions, by Procedure

6/3 Procedure



7/3 Procedure



Note: Vertical red line is minimum authorized radar separation for same runway arrivals to qualified runways.

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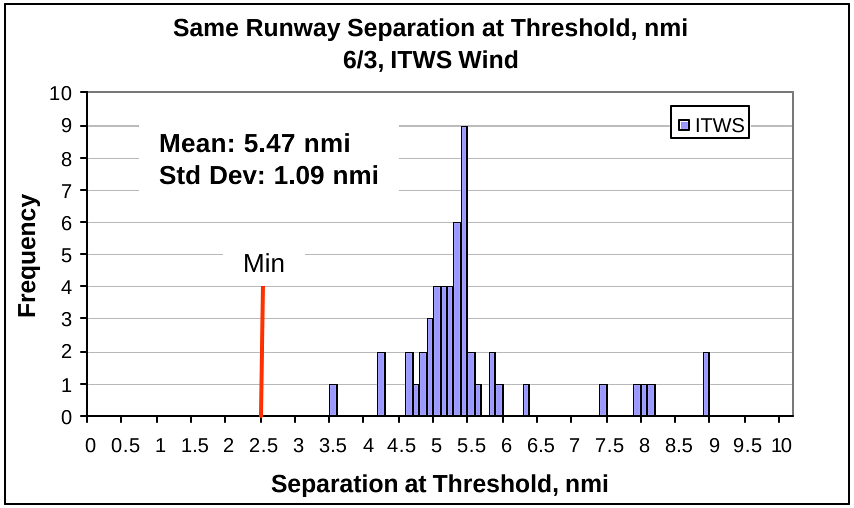
Same Runway Separation at Threshold, All Wind Conditions, by Procedure

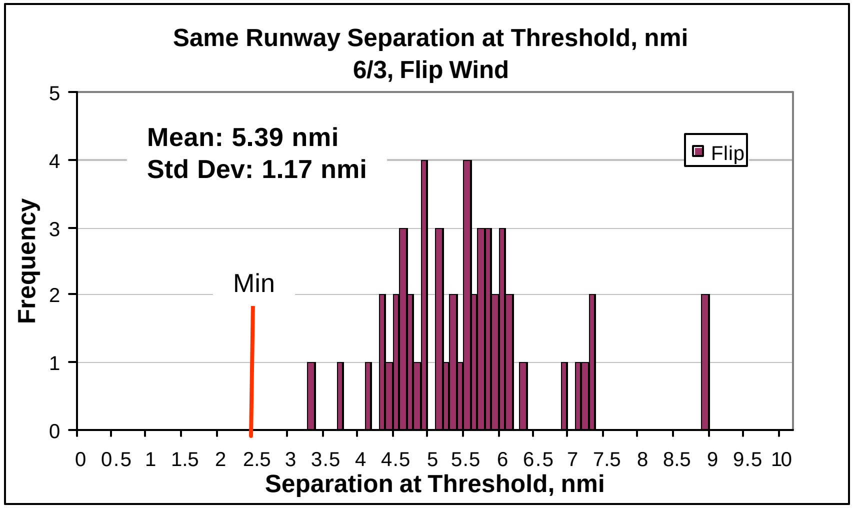
The graphic depicts the distribution of same runway separation by procedure type (6/3 versus 7/3) across wind conditions in Simulation 3. Means and standard deviations are also displayed. The tighter average spacing in the 6/3 procedure yielded the highest landing rates in those scenarios where the 6/3 procedure was in use, approaching the rates associated with the LDA operations conducted in visual meteorological conditions. (See Slide 35).

Same Runway Separation at Threshold, 6/3 Procedure, by Wind Condition

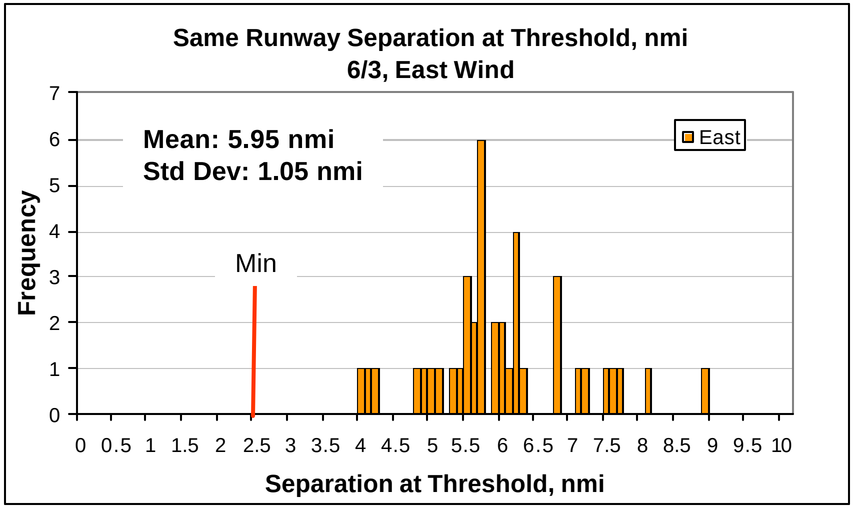
ITWS



Flip



East



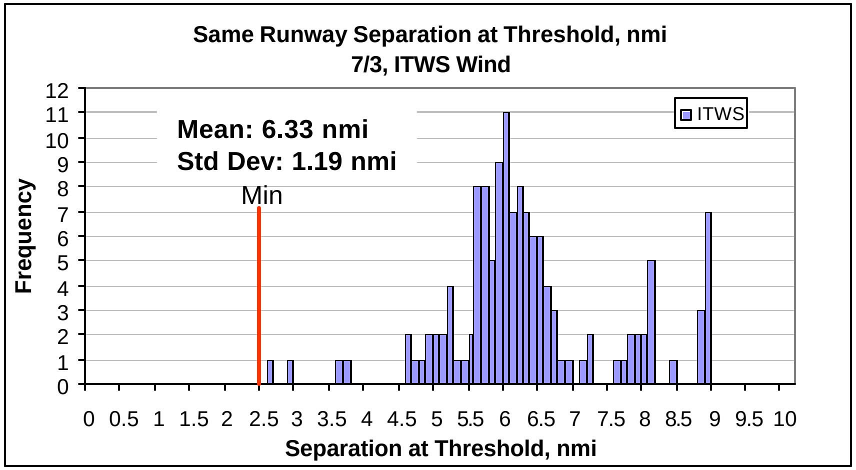
Note: Vertical red line is minimum authorized radar separation for same runway arrivals to qualified runways.

Same Runway Separation at Threshold, 6/3 Procedure, by Wind Condition

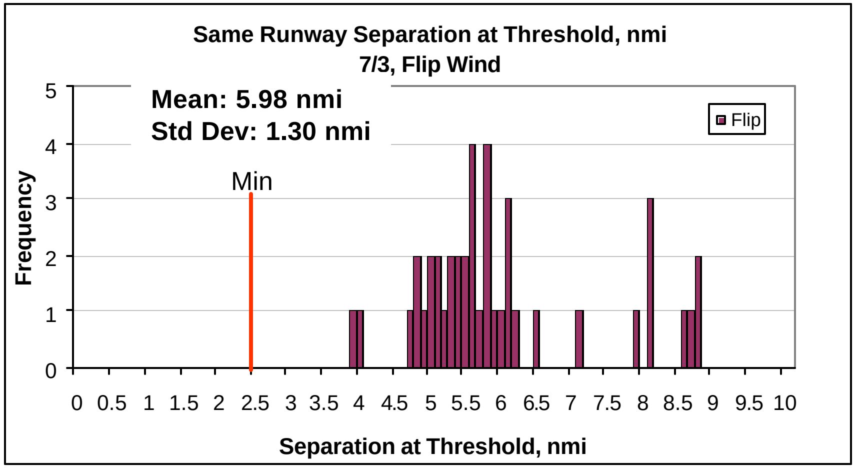
The distribution of same runway separation by wind condition for the 6/3 procedure is depicted below. East wind data is from that portion of transition Scenario 7 during which 6/3 procedure was in use. The Flip wind condition shows a slightly smaller mean spacing, reflecting the effect of compression in the headwind-to-tailwind environment. Mean spacing for all wind conditions was well above the minimum required to release departures.

Same Runway Separation at Threshold, 7/3 Procedure, by Wind Condition

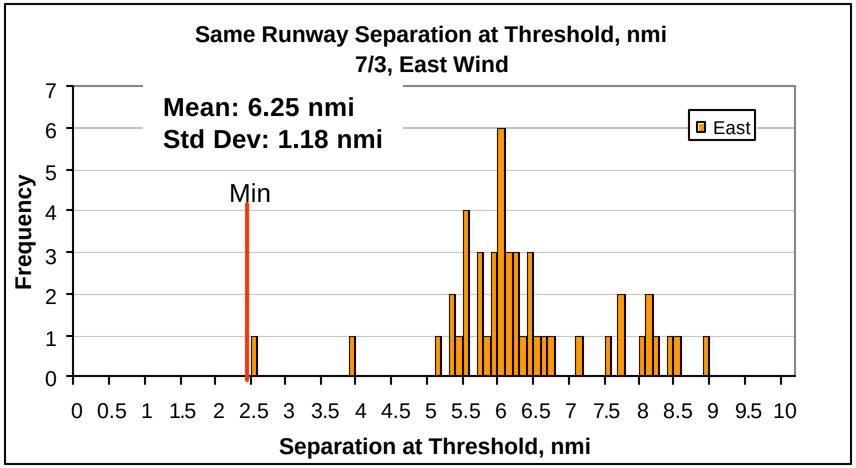
ITWS



Flip



East



Note: Vertical red line is minimum authorized radar separation for same runway arrivals to qualified runways (including STL).

Same Runway Separation at Threshold, by Wind Condition, 7/3 Procedure

The distribution of same runway separation by wind condition for the 7/3 procedure is depicted. ITWS wind data includes that portion of transition Scenario 6 during which 7/3 procedure was in use. The Flip wind condition shows a slightly smaller mean spacing, reflecting the effect of compression in the headwind-to-tailwind environment. Mean spacing for all wind conditions was well above the minimum required to release departures.

Approach Spacing Data: Points where Selected Longitudinal Spacing Values are Reached

- Current spacing requirements for ILS approaches in IMC
  - Lateral or altitude separation until both aircraft are established on localizer
  - For parallel approaches to runways separated by more than 2500 ft dependent 1.5 nmi (diagonal) spacing is authorized.
  - For single runway operations or when parallel runway separation is less than 2500 ft, 2.5 or 3.0 nmi, depending on demonstrated runway occupancy time and radar location
- While applying the new rule authorizing 1.5 nmi diagonal spacing, the actual spacing usually didn't fall below 2.5 or 3.0 nmi until both aircraft were inside the final approach fix, and in no case farther than 12.5 nmi from the threshold
- This data will be useful in performing required safety analyses of the new procedures

Approach Spacing Data: Points where Selected Longitudinal Spacing Values are Reached

For safety analysis purposes it will be useful to know at what point in the approach the certain spacing criteria are reached. Under the current rule, when conducting ILS approaches lateral/longitudinal or vertical separation must be applied until the aircraft are established on their respective localizers and are tracking toward the airport. Once both aircraft are established on the localizer, altitude separation is no longer required, but longitudinal separation must be maintained. For approaches to a single runway the minimum longitudinal separation (non-757 or Heavy, same weight category) is either 3.0 or 2.5 nautical miles. The application of the 2.5 or 3.0 nmi minimum separation at the threshold depends on runway occupancy time, the ARTS radar location, and the radar's distance to the runway threshold. Wake turbulence separation according to the relative weight category of the aircraft must be applied at all times. For the proposed dependent parallel ILS approaches the minimum diagonal separation is 1.5 nmi, assuming Large and Small aircraft.

2.5 nmi is the minimum authorized along track spacing between two Large weight category aircraft arriving on the same runway. when both aircraft are within 10 miles of the threshold, 40 miles of the radar site, and the runway occupancy time has been demonstrated to be 50 seconds or less. 3.0 nmi is the minimum for runways that do not meet the requirements stated above and when either aircraft is more than 10 miles from the threshold and other separation (e.g., altitude separation) is not being applied. Data for each successive pair is included.

It can also be seen that even a 3 nmi diagonal spacing between aircraft on the parallel approaches was also generally not reached until after final approach fix, and never until 12.5 nmi (9.5 +3.0) from the threshold.

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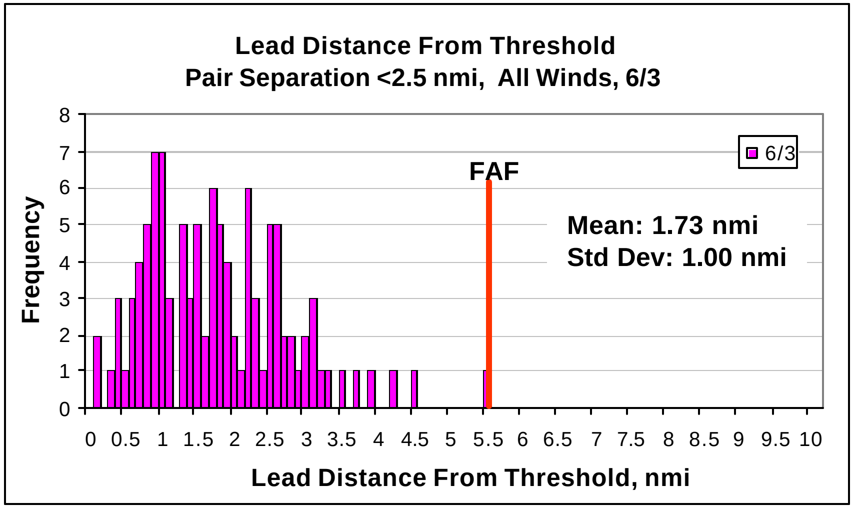
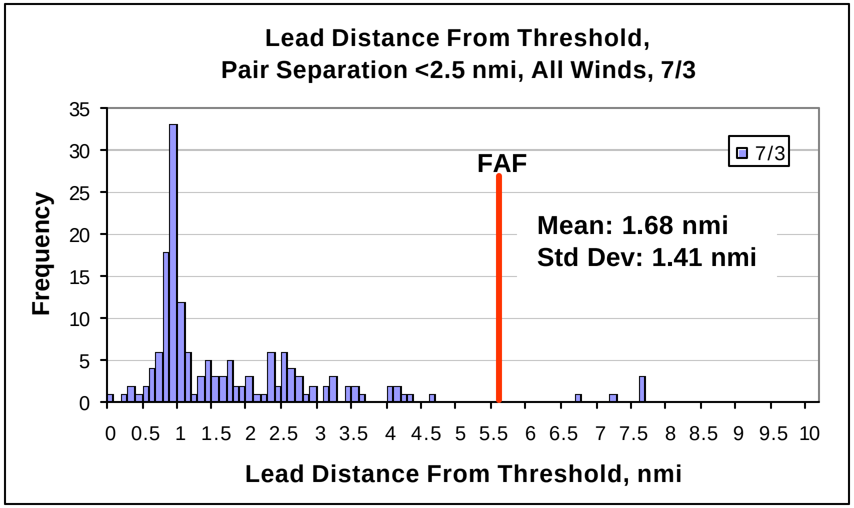
Lead Distance From Threshold When Diagonal Spacing Reduced to Less than 2.5 nmi, All Wind Conditions, by Configuration

6/3 Procedure



7/3 Procedure



Note: Vertical red line is the final approach fix distance from threshold (5.6 nmi for both ILS 12L and ILS 12 R at STL).

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Lead Distance From Threshold When Diagonal Spacing Reduced to Less than 2.5 nmi, by Configuration, All Wind Conditions

The histograms on the preceding page illustrate the distributions of distance from threshold of the lead aircraft, when the diagonal separation of a pair of aircraft on adjacent runways becomes less than the specified value in this case 2.5 nmi. It can be seen that 2.5 nmi spacing was never reached until the leader was at least 7.7 nmi from threshold, i.e., when both aircraft were within about 10 nmi of the threshold (in the 7/3 procedure, 7.7+2.5=10.2 nmi).

In the 7/3 procedure data the effect of the extra spacing between the trail aircraft of one arrival pair and the lead of the next pair can be seen in the skew of the distribution toward smaller lead distance from threshold when the separation becomes less than 2.5 miles. The extra distance between the pairs of arrivals allows the trail aircraft in one pair to get closer to the threshold before the lead aircraft in the next pair breaks 2.5 miles. In the 6/3 procedure the effect of the more continuous spacing between arrival pairs is apparent in the less skewed distribution.

In the 7/3 procedure It can be seen that even though the candidate procedure authorizes 1.5 nmi for the entire final approach course, that in fact even a 2.5 nmi spacing was generally not reached until after the final approach fix, and never reached until within about the last 10 nmi of the approach.

The vertical red line in the graphs is the final approach fix distance from threshold (5.6 nmi for both ILS 12L and ILS 12 R at STL) In nearly all cases the lead aircraft in an arriving pair is inside the Final Approach Fix for that approach before diagonal spacing between aircraft on parallel approaches is reduced below 2.5 nmi.

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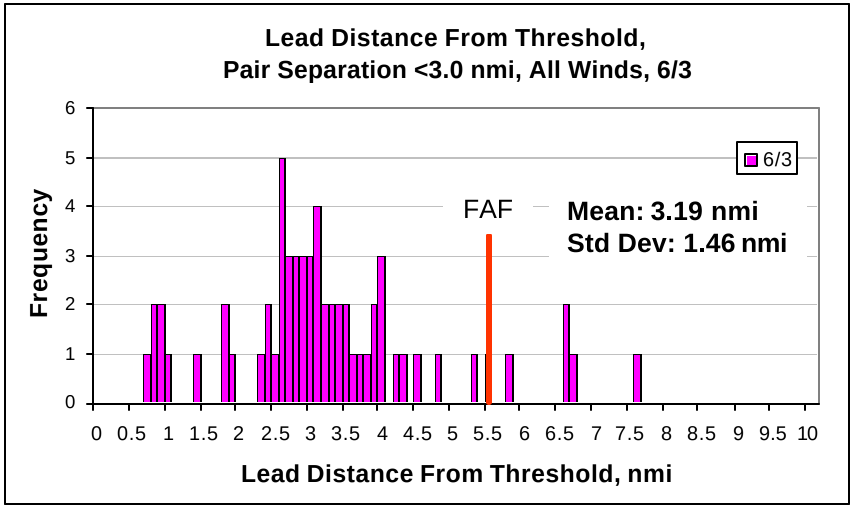
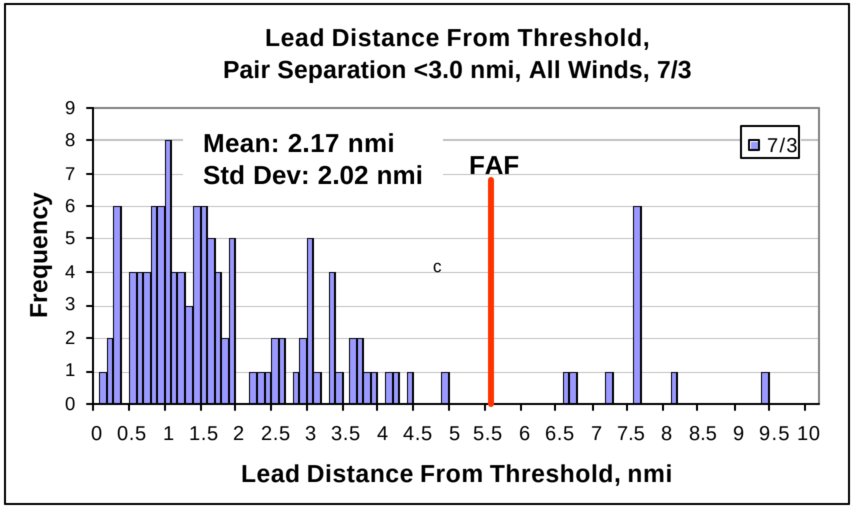
Lead Distance From Threshold When Diagonal Spacing is Reduced to Less than 3.0 nmi, All Wind Conditions, by Configuration

6/3 Procedure



7/3 Procedure



Note: Vertical red line is the final approach fix distance from threshold (5.6 nmi for both ILS 12L and ILS 12 R at STL).

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Lead Distance From Threshold When Diagonal Spacing is Reduced to Less than 3.0 nmi, All Wind Conditions, by Configuration

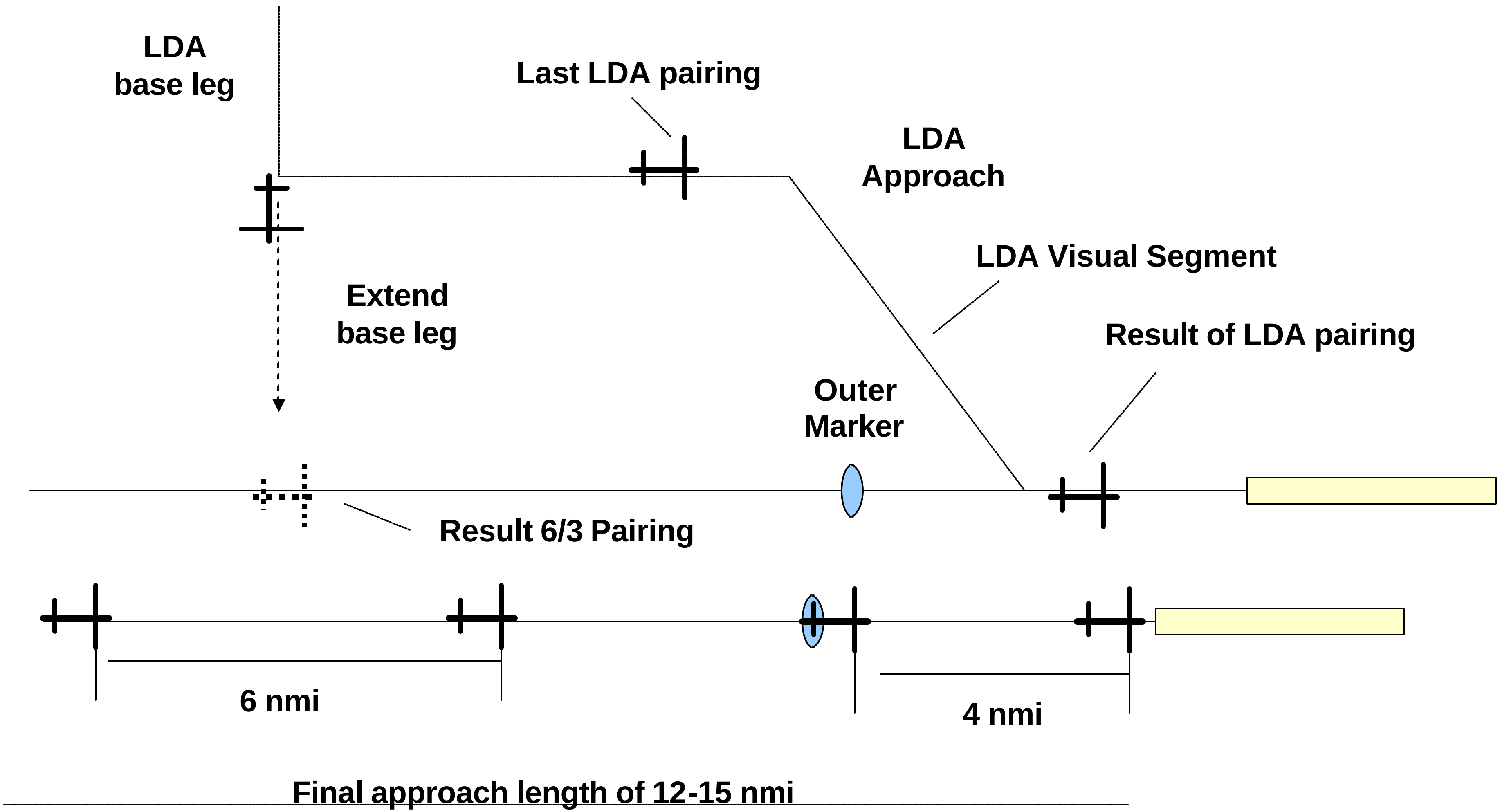
The previous histograms illustrate the distributions of distance from threshold of the lead aircraft, when the diagonal separation of a pair of aircraft on adjacent runways becomes less than the specified value, in this case 3.0 nmi. It can be seen that 3 nmi diagonal spacing between aircraft on the opposite approaches was generally not broken until after final approach fix, and *never* broken until 12.5 nmi (in the 7/3 procedure, 9.5 +3.0) from the threshold.

The distance at which 3 nmi spacing is broken in the 7/3 procedure appears to be bi-modal, due to the smaller distance between the leader and trailer in a pair, than the distance from the trailer of one pair to the leader of the next. There are also more occurrences outside the final approach fix since aircraft meet the criterion earlier in the approach.

Additional Results

- **Results of lab participant debriefings**
  - **The controllers indicated that the candidate procedures could be conducted by the general work force at STL with appropriate training**
  - **Controllers also indicated that**
    - **as simulated, they saw no need for an additional separation monitoring position (e.g., similar to the Local-3 position used for CRDA in STL tower) for this procedure**
    - **they understood and agreed that no monitor or other assistance was indicated or needed in approach control for assuring the separation required by this procedure**
    - **no potential issues with respect to display resolution in the operational environment with the current displays were identified**
  - **It should be understood that these results may need to be revisited as part of the safety analysis of the procedure**

STL Specific Finding
Transition To/From LDA Approach



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STL Specific Finding
Transition To/From LDA Approach

Today's operations at STL require transition from LDA/ILS operations to a converging runway operation when the ceiling drops below 1200 ft. The least disruptive of the possible alternate configurations transitions from LDA operations on 12s to the converging runway operation is to 12R and 6, where traffic from 12L must be brought over to 6. Controllers report that this is a workload intensive and complex reconfiguration of traffic.

Of specific interest to STL was to identify whether there were operational issues related to the transition to and from their LDA offset approach to any of the parallel ILS procedures being considered. The transition from LDA offset approach to a 6/3 approach is presented on the previous page. As weather deteriorates, the traffic manager identifies a final pair of arrivals to use the LDA approach and the feeder controllers begin to establish 6 nmi in trail for subsequent aircraft. Once a sufficiently long final is established by the South final controller, the North final controller can begin diagonally spacing the arrival for the first pair. North final aircraft can simply fly an extended base leg to intercept the ILS 12L localizer. The same technique would apply to either the 6/3 or 7/3 procedure.

Likewise transitions from any of the 1.5 nmi diagonal separation minimum concepts back to LDA approaches would be straight forward. The traffic manager identifies the final pair of aircraft to use the 6/3 procedure and feeder controller begin to establish the desired in trail separation for LDA approaches. The North final controller will shorten the base leg to intercept the LDA localizer. The airport arrival rates for 6/3 and the other concepts of use are somewhat lower than for the LDA approach, so there is expected to be no delay in traffic due to the configuration change back to LDA approaches.

In addition, each of the concepts of use for 1.5 nmi diagonal separation minimum provide a transition from a non-precision approach (LDA) without vertical guidance, to a precision approach to 12L with vertical guidance. These differences should be accounted for during the overall safety assessment of the operational application of 1.5 nmi diagonal separation minimum in comparison to today's operations.

Extensibility to Other Facilities

- Operations at most facilities are unique. The main challenges considered in this study were:
  1. Could the proposed change in separation rules be supported by ATC, especially with respect to workload and general feasibility?
  2. Will the new operation raise airspace, training or other issues?
  3. Will operations with realistic conditions such as departure demand, winds, etc. inhibit ATC operation or present specific limitations?
- First and third challenges can be answered positively for a broader application in the NAS
  – This study has shown that workload involved in the proposed change in standards is not prohibitive
  – The study also indicates that ATC procedures for operational implementation of the new rule change are possible
- Resolution to challenge 2 will be site specific and must be considered in the context of each site

Extensibility to Other Facilities

It is well known that operations at most busy approach control and tower facility in the NAS can be quite unique, and facility specific considerations are almost always needed for any new procedure.

The main challenges considered in this study were:

1. Could the changes in separation rules proposed by this procedure be supported by ATC, especially with respect to the increase in workload
2. Will the new operation raise local airspace, training or other issues
3. Will operations with realistic conditions such as departure demand, winds, etc. inhibit the operation or present specific limitations

It is felt that the first and third issues can be answered positively for a broader application in the NAS. The second item is always site specific and must be addressed individually for a site.

In particular, this study has shown that workload involved in the proposed change in standards is not prohibitive. It also indicates that formulation of ATC procedures for operational implementation of the new rule change are possible. However, actual application at a particular facility is often site specific. Some factors that contributed to the design and acceptance of at least one of the two candidate procedures (the 7/3 procedure) presented in this study were helped by the fact that similar procedures, its LDA approaches, already existed at STL. However, most of the factors that enabled the acceptance of at least the 6/3 procedure were not site specific. This suggests that local procedures to apply these proposed standards to their operations could readily be found by other facilities that have some motivation to do so.

Further Issues
Blunders and Other Non-Normal Events

One of the issues that will need to be addressed in implementing this procedure is that of how to handle non-normal occurrences and to ensure that the safety impact of foreseeable can be mitigated in a satisfactory way. During Simulation 1, several blunder events and premature decelerations were scripted to occur. After discussion with the controllers it was determined that the current ATM Lab display configuration does not have two key attributes that controllers regularly use to monitor localizer intercept performance. The first is the raw target position display that is normally present with the controller ID letter on the display. This is the indication of absolute target position and controllers use it to determine target position with respect to the localizer. This capability could not be developed in time to be included in this series of simulations. Secondly, the zoom scales available for the Plan View Display were too coarse to provide the display scale that controllers were used to using. As a result, controllers were required to operate at a smaller scale than desired. In terms of blunder detection, it resulted in a smaller interval between localizer centerlines that would reduce the ability to detect blunders. Therefore, it was not possible to properly investigate blunders, and response to blunders remains an open issue that will require additional laboratory modifications to properly address.

Likewise detecting early decelerations proved to be difficult because the scripted deceleration point occurred at a position just before or just after the flight had already been handed off to the tower. During Simulation 1 a tower local position was not simulated or staffed and therefore TRACON controllers had no way of responding to early slowdowns when they occurred. It is also the case that once turned over to the tower the local controller will also be monitoring separation using the BRITE display. In Simulations 2 and 3 we saw several instances of the local controller detecting impending separation problems.

In summary, the issue of blunders and other non-normal events is still open and will require further research and analysis.

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Conclusions of HITL Simulations

- **ATC application of the proposed new rule change (1.5 nmi diagonal separation for runways separated less than 2500 ft) appears feasible and desirable**
  - **A range of operationally feasible candidate procedures of 1.5 nmi diagonal separation were identified**
  - **Several candidate procedures have been developed to allow controllers to conduct traffic with an acceptable workload level, under a demanding range of wind conditions and with a typical mix of 757s and Heavies**
- **STL controllers were able to achieve the following rates with a mix of arrival traffic typical for that facility**
  - **Arrival rates for 6/3 candidate procedure approximated 50 per hour**
  - **Arrival rates for 7/3 candidate procedure approximated 45 per hour**
  - **Simultaneous departure rates approximated 40 per hour for both candidate procedures**
- **Acceptance rates were encouraging**
  - **Support the results of previous fast-time capacity analyses**
- **Although some aspects of the feasibility of the candidate procedures were facilitated by current STL site-specific operations, most appeared to be suited for general application**
  - **Candidate procedures may still require some adaptation for site specific needs**
- **Within the scope of the HITL experiments, these results support continued pursuit of a modified 2500 ft rule for CSPR**

Appendix
Supporting Material

Considerations in Authorizing the Proposed New Rule Change

- The rule change proposed and evaluated here is based on the hypothesis that wakes are not a factor behind Large and Small aircraft for trailing aircraft on parallel approaches spaced 1000 ft or more laterally from approach of leading aircraft
  - Existing data from SFO and other previous sources suggests this hypothesis
  - Collection of weather and wake turbulence data is underway at STL to provide a basis for assessing this hypothesis
- An appropriate safety analysis by Flight Standards is required to define the minimum runway centerline separation for which this proposal may be authorized
- References: SFO report (to be released shortly), Lang, et al. (2003) and Domino. et al. (2003)

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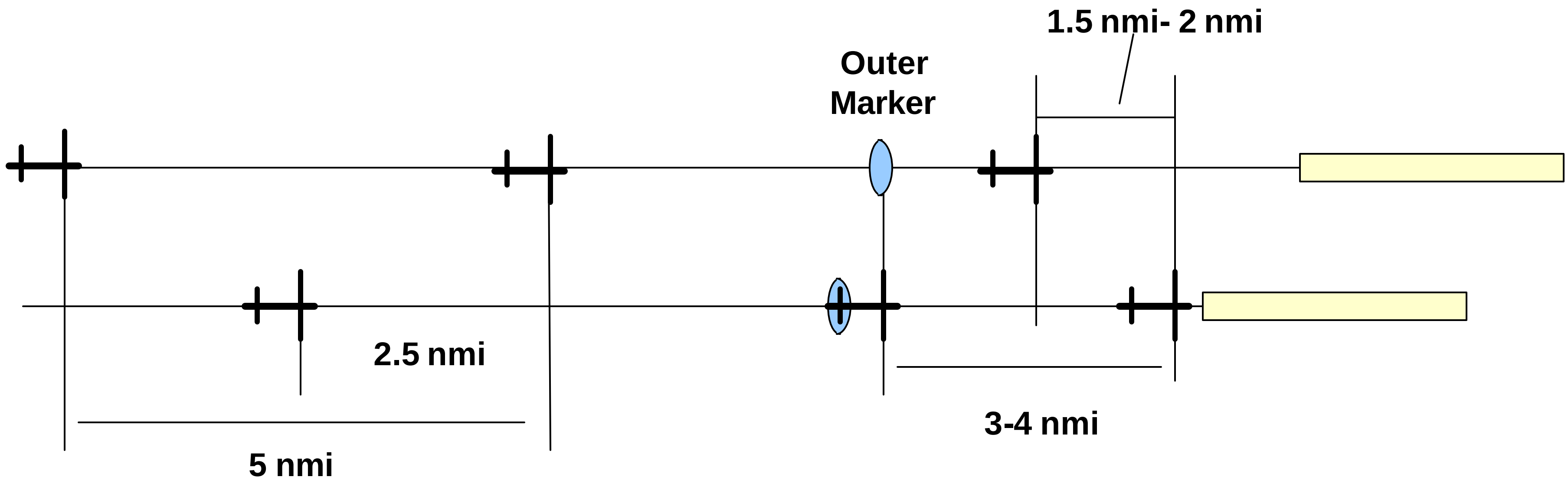
Detailed Description of Procedure Variations

- Several variations on each procedure were reviewed:
  - A "shortened" variation on the 6/3 procedure which can be used for a heavier arrival demand
    - In this concept controllers vector to a same-runway-separation of 5 miles at localizer intercept, yielding about 2.5 miles separation between the successive arrivals on alternate runways
    - This technique would not be available under extreme wind conditions due to excessive compression on the final approach as aircraft reduce to final approach speed, and fly out of the tailwind and into the headwind
  - The "stretched" variation of the 6/3 procedure that extends the separation between pairs of arrivals
    - In this concept, same runway separation at localizer intercept is increased to 7 or 8 miles so that runway and pair separation would allow two departures between each arrival
  - A version of the 7/3 dependent procedure (1.5 nmi "Power Stagger") that extends the separation between pairs of arrivals
    - Intended to accommodate a Heavy departure demand, occasionally enabling two departures between arrivals

"Shortened" 6/3 Approach

At turn on: 5 nmi in trail separation, 2.5 nmi diagonal
At threshold: 3 - 4 nmi in trail and 1.5 to 2 nmi diagonal



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“Shortened” 6/3 Approach

The symmetric procedure presented on the previous page is a shortened variation of the 6/3 procedure. In trail separations of 5 nmi at the localizer intercept are provided for arrivals on each runway. This separation results in in trail separation at the threshold of 3 nmi or more, allowing the airport to increase its AAR during an arrival push, but minimizes opportunities for releasing departures. Diagonal separation of 2.5 nmi at glide slope intercept provides adequate separation to accommodate the compression effects of aircraft speed reductions around the Outer Marker and additional compression effects from tail wind to head wind transitions along the final approach. Typical delivery of diagonal separation as measured at the threshold is 1.5 to 2 nmi.

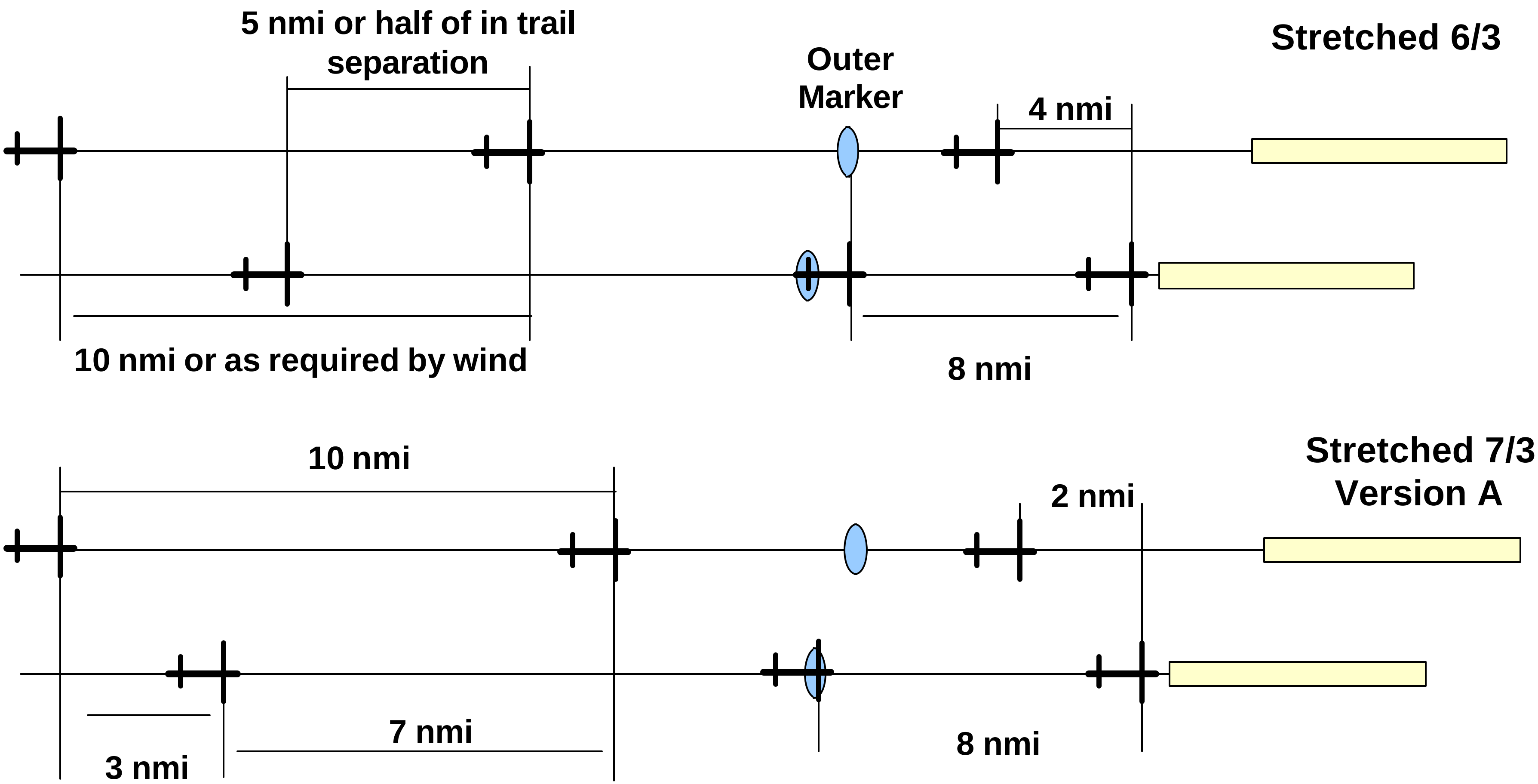
Vertical and along track separation responsibilities are as previously described for the other procedures.

The depiction of the concept on the previous page shows the relative positioning of Large and/or Small when a 1.5 nmi diagonal separation minimum can be applied between them. The concept of use also addresses the procedures for handling Heavy and 757 aircraft where standard wake separation is required behind these aircraft. As in the previous procedures the feeder controller delivering the will establish appropriate separation behind the Heavy or 757 aircraft depending on the trailing aircraft type and the amount of compression expected on final approach. The other feeder controller (or final approach controller) will also adjust separation as required, for aircraft on the parallel approach. The Heavy or 757 aircraft will be turned on final with no paired aircraft trailing. Thus standard wake separation behind Heavy and 757 aircraft is provided in trail, and the shortened approach configuration resumes after the trailer to the Heavy or 757 aircraft.

The implementation of a 1.5 nmi diagonal separation minimum applies only to final approach when both lead and trailing aircraft are established on the ILS. This requires one of the final approach controllers, in the case of STL the North final controller, to maintain vertical separation with both the lead and trailing aircraft on the parallel approach path until both are established on the localizer.

No specific runway assignment is required for Heavy or 757 aircraft in this concept of use, nor is there a leader-trailer assignment to a specific runway. The results of the wake turbulence safety analysis by Flight Standards will define the combination of minimum runway centerline separation and maximum threshold displacement for which this concept of use may be applicable.

Stretched Procedures



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Stretched Procedures

The stretched 6/3 procedure and stretched 7/3 dependent procedure are presented on the preceding page. These procedures were designed specifically to investigate operational issues related to departing two aircraft for every arrival. In both these concepts of use, the in trail separations of 10 nmi at the localizer intercept are provided for arrivals on each runway. This initial separation delivers in trail separation at the threshold of 8 nmi or more, allowing the local controller to release two departures for each arrival. The difference between both stretched procedures is the choice of the final controller to place the diagonally separated aircraft symmetrically or asymmetrically between the aircraft on the other final. In the case of STL where the southern approach traffic is 1000 ft below the northern final approach traffic, the northern final controller is the one to makes that decision. In the case of the stretched 6/3 procedure, the 10 nmi separated traffic on the left approach provides a visual aid for merging in the right approach traffic to the middle of the right runway arrivals. In the case of the stretched 7/3 procedure, the North final controller will merge his arrivals in at about 3 nmi diagonal separation from the leading arrival on the right runway.

Vertical and along track separation responsibilities are as previously described for the other procedures.

In contrast to the 6/3 procedure and the 3 nmi diagonal separation at glide slope intercept, the North final controller is not required to maintain vertical separation from both the lead or trailing aircraft on the parallel approach path until both are established on the localizer. In the case of the stretched 7/3 procedure, the North final controller is required to maintain vertical separation only from the lead aircraft on the parallel approach path until the lead aircraft is established on the localizer, since standard radar separation or greater will exist between the trail aircraft of the preceding pair and lead aircraft of the following pair.

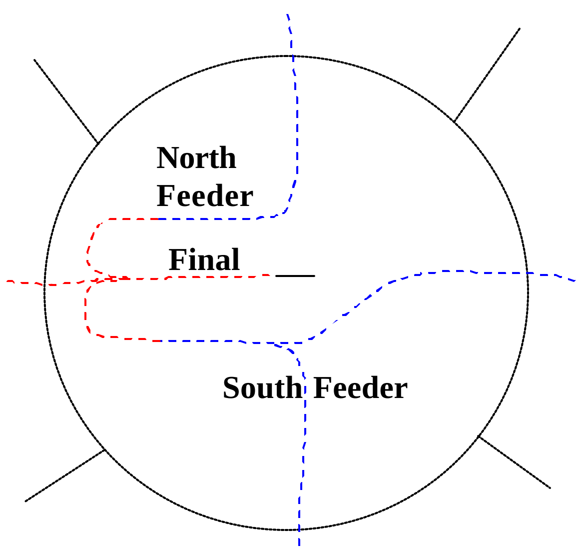
For the stretched 6/3 procedure, the concept of use also addresses the procedures for handling Heavy and 757 aircraft where standard wake separation is required behind these aircraft. The feeder controller will ensure 10 nmi of in trail separation behind the Heavy or 757. The other feeder controller (or final approach controller) will provide a gap, essentially a 20 nmi separation between aircraft, for the parallel approach. The Heavy or 757 aircraft will be turned on final with no diagonal aircraft trailing. Thus standard wake separation is provided in trail, and the 6/3 configuration resumes after the trailer to the Heavy or 757 aircraft. The stretched 7/3 procedure also addresses standard wake separation behind a Heavy and 757 aircraft by assigning them the trailing position in a pair or by not pairing them up with a diagonal aircraft.

The results of the wake turbulence safety analysis by Flight Standards will define the combination of minimum runway centerline separation and maximum threshold displacement for which these concepts of use may be applicable.

Example Arrival Configurations

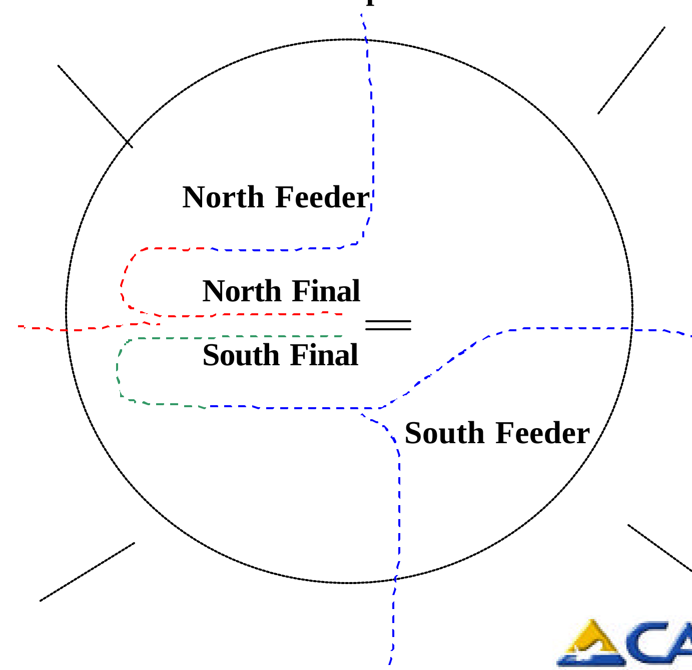
Current Single runway arrivals:

- Enroute arrival sectors feed stream of traffic to each arrival gate at 5 MIT or more usually below 250 knots
- Each feeder merges arrival streams to single flow, and coordinates with other feeder to set up streams for (one) final controller
- Final controller merges traffic from North and South sides
- North and South traffic typically separated by 1000 ft vertically until after localizer is acquired



Proposed dual runway arrivals:

- Five concepts of use investigated for feasibility, workload, training, and implications for safety analyses using this arrival configuration
- Base Procedures
  - 6/3 Procedure
  - 7/3 Procedure
- Variations
  - "Shortened" 6/3
  - "Stretched" 6/3
  - "Stretched" 7/3 Dependent Procedure



Note use of two final controllers

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Acronyms

ARTS	Automated Radar Terminal System	**ILS**	Instrument Landing System
ASDE	Airport Surface Detection Equipment	**IMC**	Instrument Meteorological Conditions
ATC	Air Traffic Control	**ITWS**	Integrated Terminal Weather System
ATM	Air Traffic Management	**LDA**	Localizer Directional Aid
BRITE	Bright Radar Indicator Tower Equipment	**MIT**	Miles in Trail
CAASD	Center for Advanced Aviation System Development	**NAS**	National Airspace System
CRDA	Converging Runway Display Aid	**NATCA**	National Air Traffic Controller Association
CSPR	Closely Spaced Parallel Runways	**SFO**	San Francisco International Airport
FAA	Federal Aviation Administration	**STL**	Lambert - St. Louis International Airport
GUI	Graphical User Interface	**TAAM**	Total Airspace and Airport Modeller
HITL	Human-in-the-Loop	**TRACON**	Terminal Radar Approach Control Facility

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